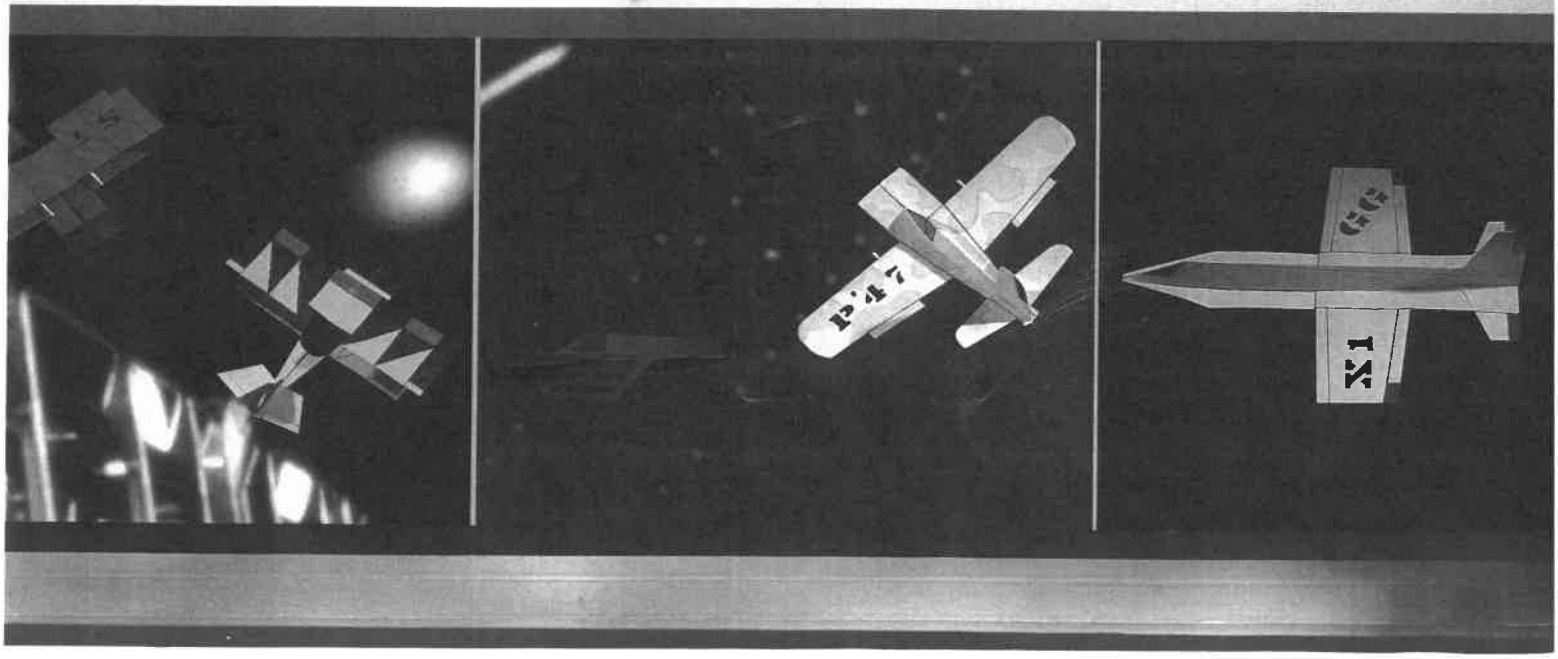
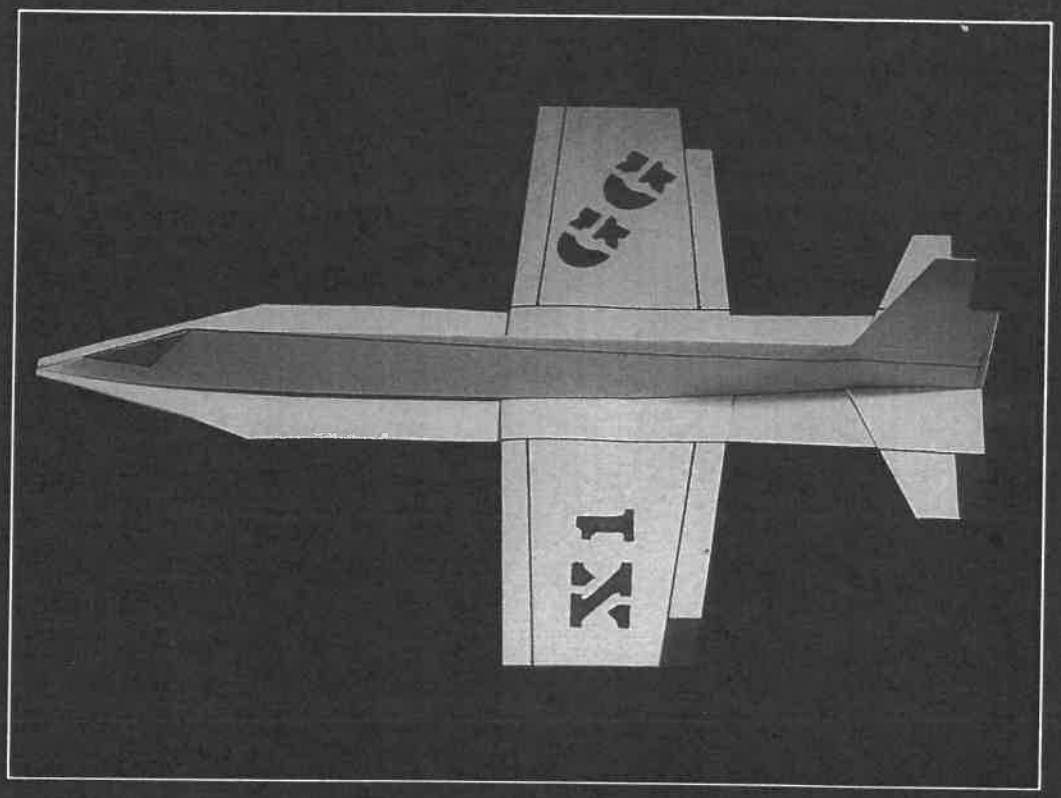
Super Paper Airplanes

Biplanes to Space Planes

Norman Schmidt



SCIENCE/CRAFTS



With nothing more than paper, ruler, pencil, scissors, glue stick, and this all-color extravaganza of super fliers, create 18 different planes that really zip through the air—and that demonstrate the history of modern flight. Begin by making the Aero Bat, modelled after the first, birdlike planes developed over a century ago. Work up to the biplane, the design used by Orville and Wilbur Wright, and progress through time to the SST Concept, a model based on a future plane that would make flying faster than the speed of sound available to ordinary travellers. Each flier has historical, technical, and scientific information, as well as detailed diagrams and instructions, and a full-color photograph that offers decorating suggestions. It's the most fun, hands-on history lesson ever, and it makes time *really* fly!

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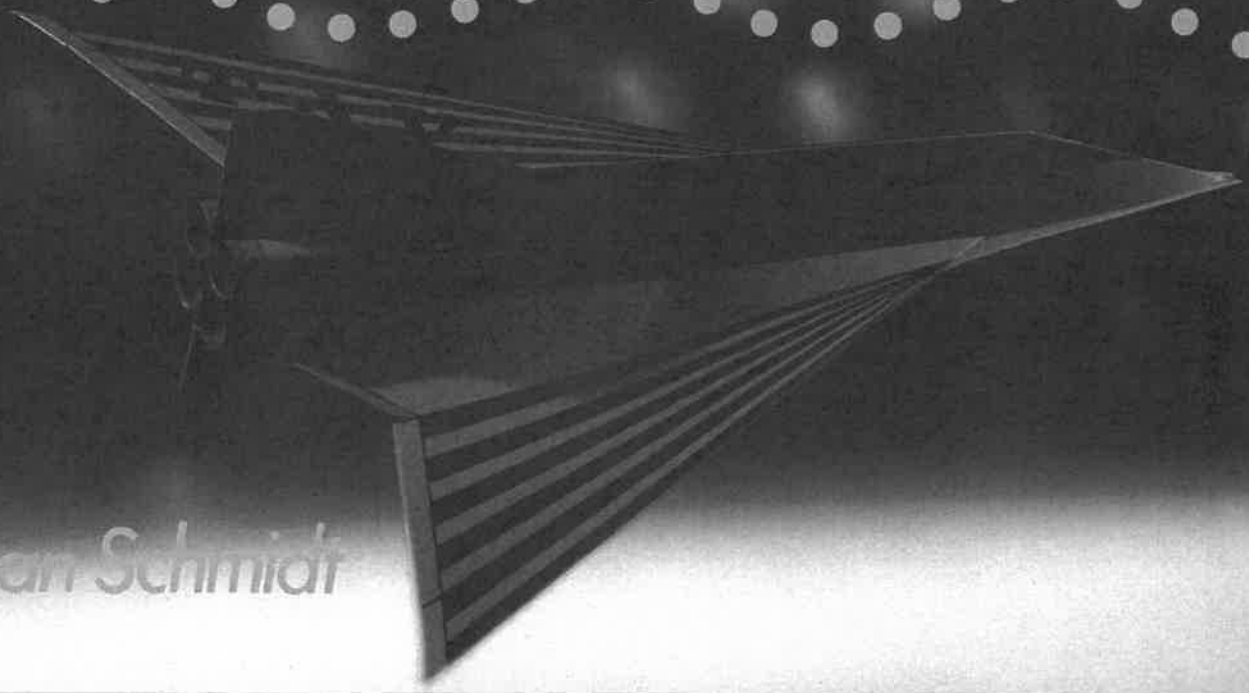

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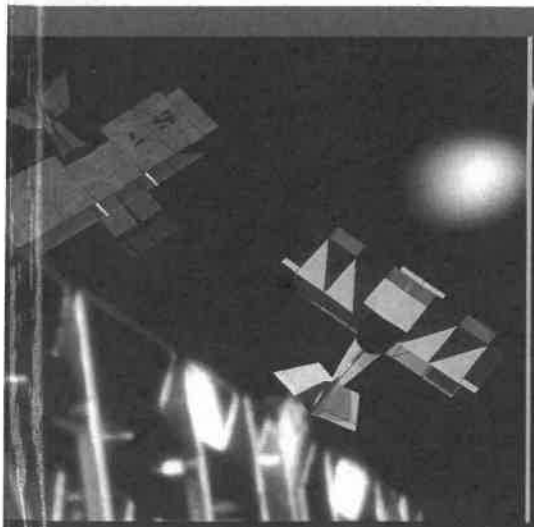

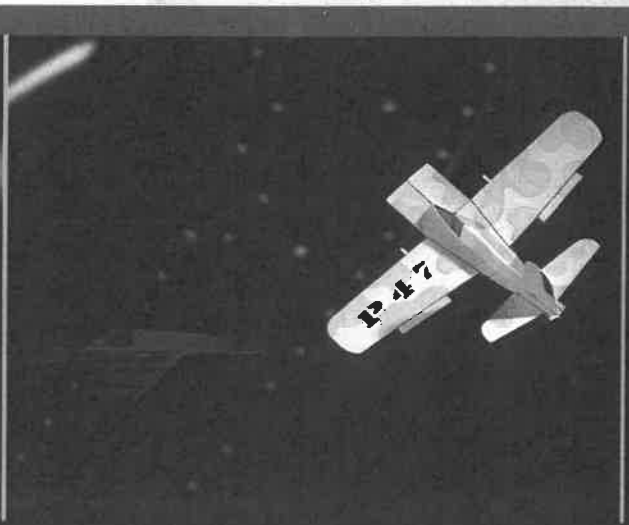

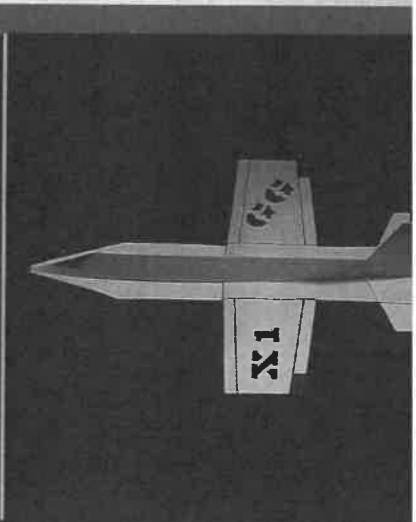

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The advice and directions given in this book have been carefully checked, prior to printing, by the Author as well as the Publisher. Nevertheless, no guarantee can be given as to project outcome due to possible differences in material and the Author and Publisher will not be responsible for the results.

Flight

People have been obsessed with the idea of flight ever since they looked into the sky and saw birds soaring gently overhead. Mythical stories in many cultures around the world have flying creatures of all sorts, including human beings. When did the reality of human flight begin?

Archeologists in Egypt have discovered a small wooden bird, carved from lightweight sycamore wood, that has a very aerodynamic shape. This small wooden bird is unlike any real bird because its tail has both horizontal and vertical surfaces, just like present-day airplanes. It is not known whether this was a toy, a weather vane, or a small model of some larger craft.

There are other examples of flying toys, such as the Saqqara bird invented by the Greek philosopher Archytas in about 345 B.C. It was a small wooden dove attached to an arm that allowed it to "lift off" in wavering flight. It is not known how the bird was propelled. At about the same time the Chinese philosopher Mo Tzu constructed what was possibly the first kite, which is simply a tethered airplane. Some Europeans made wings of wood, cloth, and bird feathers, strapped them to their arms, and jumped off high buildings. In 1020 Eilmer "the flying monk" did this, and attained some success with flight, but broke both his legs in the attempt. In the 1500s the artist and inventor, Leonardo da Vinci, made many drawings and models of different kinds of aircraft, including the parachute. Another story from the 1700s tells of a French locksmith named Besnier, who, with wings strapped to his arms and legs, jumped from a tall building and glided over neighboring houses.

The development of kites continued and they became the forerunners of free-flying airplanes. European inventors and scientists used them to carry out experiments in aerodynamic forces. Such experiments led to the first free-flying airplanes of Sir George Cayley in the 1790s. They demonstrated the principles of flight as they are understood today. In the 1850s Sir George's coachman was among the first people to fly in an actual airplane. The stage was now set for the development of controllable airplanes. That story is told through the paper airplanes that follow in this book.

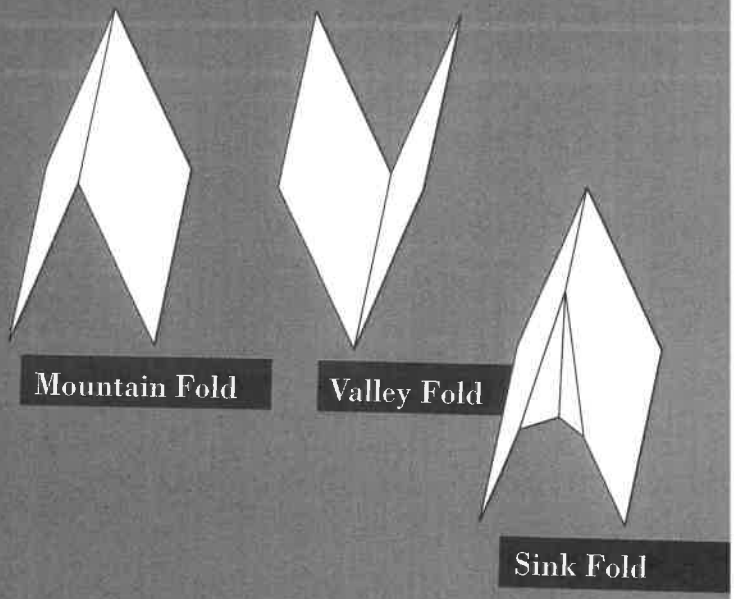
Construction

When carefully made, the paper airplanes in this book are super flyers. They can be built using ordinary 20 or 24 lb bond copier paper measuring 8-1/2 in by 11 in (21.6cm by 27.9cm). Bond paper is lightweight, easy to cut and fold, and easy to fasten together. It is available in a variety of colors (black paper may have to be purchased from an art store). Since a paper airplane's lift and thrust are limited, every effort must be made to keep drag at a minimum. Every surface not parallel to the direction of travel (wings, nose, and canopy) adds drag, so the neater and more accurate your construction, the better the plane will fly. Clean and accurate cuts and crisp folds are a top priority.

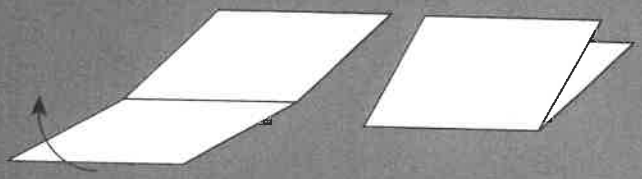
Measuring and Cutting Use a sharp pencil to mark the measurements and draw firm, accurate lines. Cut out the pieces with a sharp pair of scissors or a craft knife and a steel-edged ruler. A knife makes a cleaner cut. When using a knife be sure to work on a proper cutting surface.

Folding Always lay the paper on a level surface for folding. Folding is easier along a score line (an indented line on the paper made with a hard pencil drawn along a ruler). There are only three kinds of folds used in making the airplanes in this book. They are mountain folds, valley folds, and sink folds. Where multiple layers are folded, run your fingers back and forth along the fold pressing hard to make a sharp crease.

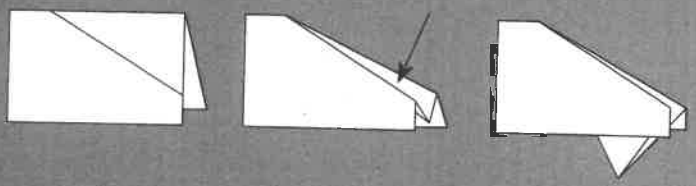
Gluing A glue stick works well for paper airplanes. Follow the instructions for gluing. Cover the entire contacting surfaces that are to be joined. If there are multiple layers, apply glue to each of the sheets. Glue should be used sparingly, but use enough to hold the parts together. Where multiple layers are being joined you may need to hold the pieces for a few minutes until the glue sets.



A mountain fold and a valley fold are actually the same kind of fold. Both are made by folding a flat piece of paper and sharply creasing the fold line. The only difference is that one folds up (valley fold) and the other folds down (mountain fold). They are distinquished only for convenience in giving instructions.



To make a sink fold, begin with paper that has been folded using a mountain (or valley) fold and measure as required across the folded corner. Then push in the corner along the measured lines, making a diagonal fold. Finish by creasing the folds sharply.



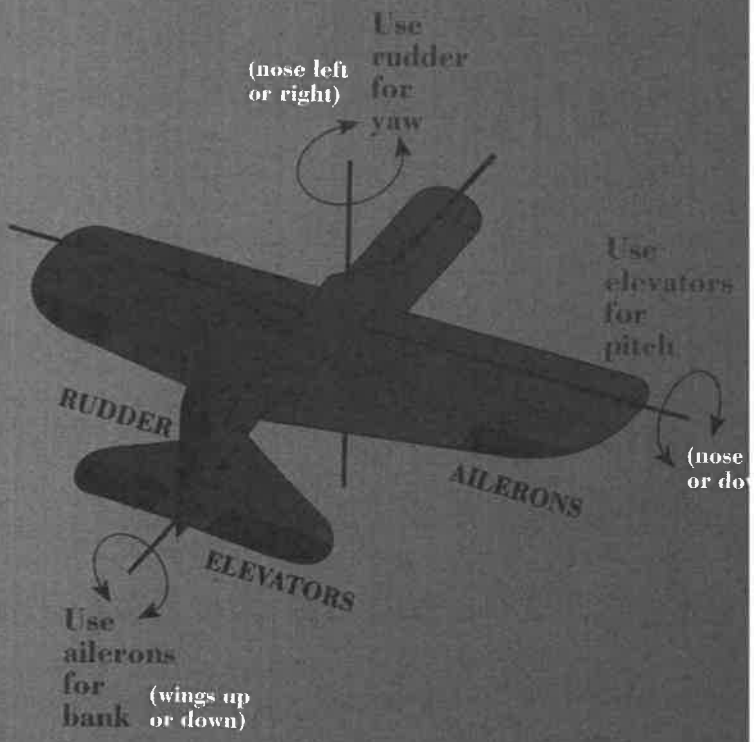
Trimming for Flight

Air is made up of small, solid, evenly spaced particles called molecules. Everything in the universe is made up of molecules, but air molecules are quite far apart compared to those that make up metal, wood, or paper, and they are easily separated when a body moves through them. The molecules are piled up in a thick layer from the ground, and this is called the atmosphere. It forms part of the space around us and the sky above us. This layer of air molecules (atmosphere) exerts pressure on everything in the world and it is this pressure that makes flight possible. The shape of the airplane affects the molecules as they move across the airplane's surfaces, increasing or decreasing air pressure, determining the flight characteristics of the plane.

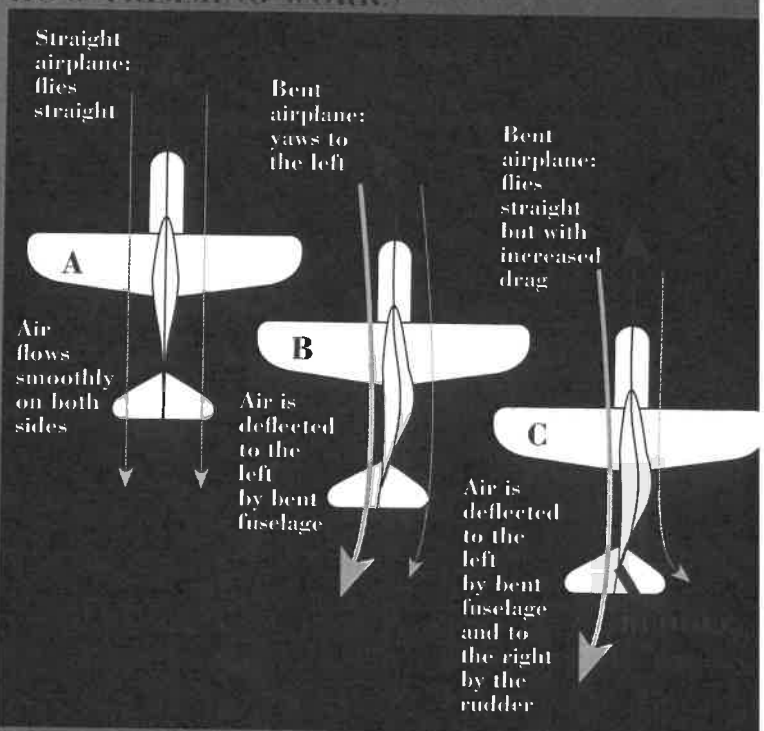
No paper airplanes are perfectly straight. And they are easily bent. Shown right below is an example of trimming using the rudder. Airplane A flies straight because air flows smoothly along its surfaces. It needs no trim. Airplane B yaws to the left because the air on the left is deflected by the bent fuselage, increasing air pressure on that side. The rudder is used to compensate. Airplane C again flies straight because it has been trimmed so that the deflected air on the left is opposed by air being deflected by the rudder on the right. But airplane C does not fly as well as airplane A because it is creating much more drag.

Before making any trim adjustments to a paper airplane that you have just constructed, be sure you are releasing the plane correctly for flight. Always begin with a gentle straight-ahead release, keeping the wings level. Hold the plane between thumb and forefinger just behind the center of gravity. As your technique improves you can throw harder, adjusting the trim as needed. But remember, all planes do not fly at the same speed.

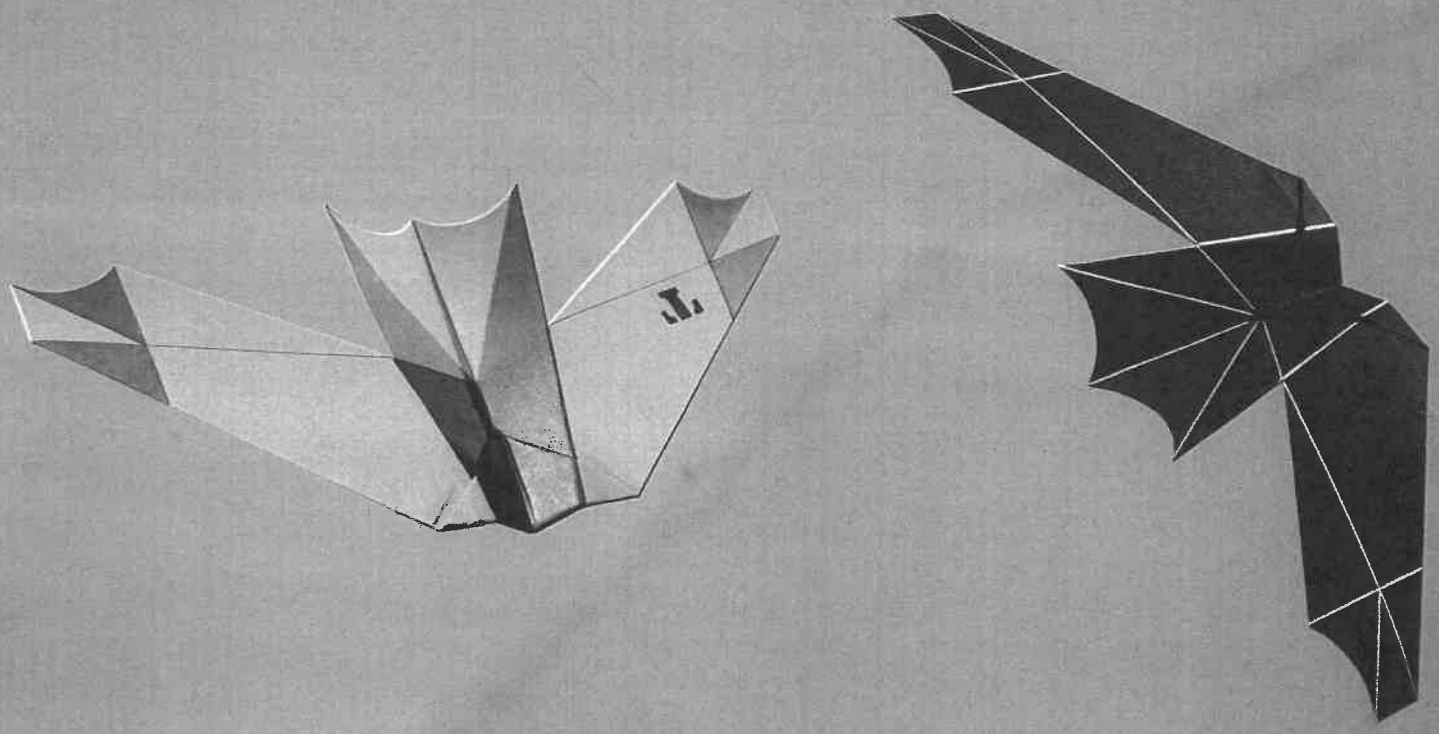
AIRPLANE CONTROL SURFACES



HOW TRIMMING WORKS


Straight airplane: flies straight
Bent airplane: yaws to the left
Bent airplane: flies straight but with increased drag
A
B
C
Air flows smoothly on both sides
Air is deflected to the left by bent fuselage
Air is deflected to the left by bent fuselage and to the right by the rudder

Aero Bat



HISTORICAL INFORMATION

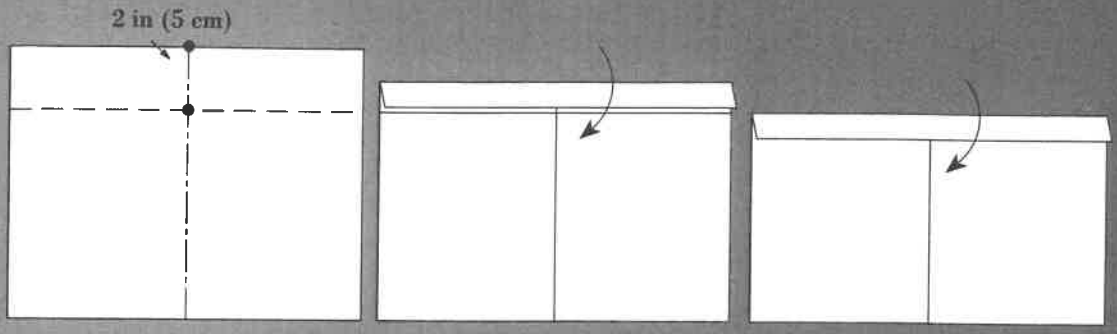
The earliest aircraft designers looked to birds and bats for clues about airplane construction. They built them with thin wooden frames cross-braced with wires and covered in fabric. For control while in flight, the wing tips could be bent up or down as necessary by the pilot. But the airplanes were flimsy and difficult to fly. They often fluttered badly and some collapsed. Many crashed. Between the 1790s and the 1890s Sir George Cayley, Francis Wenham, Percy Pilcher, Lawrence Hargrave, Otto Lilienthal, and others, experimented with various bird-like airplane designs. This paper airplane is modeled on early bird-like planes.

SCIENTIFIC INFORMATION

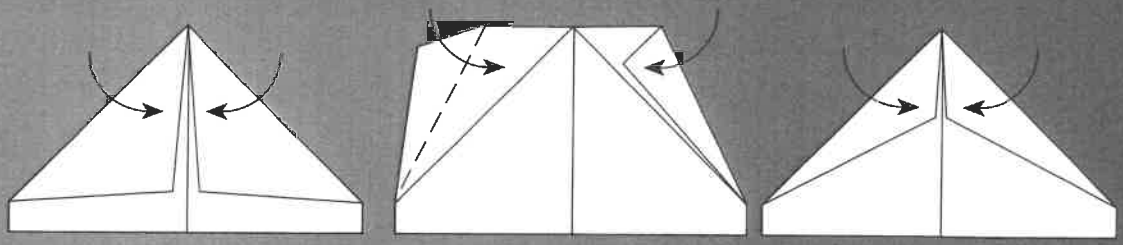
Lift When a wing having a curved upper surface moves forward it slices the air into two layers – one above and one beneath the wing. Both air layers are made up of the same number of molecules, but those that move over the curved top of the wing have farther to go. So they must speed up and spread farther apart which causes them to exert less downward pressure. The molecules of air beneath the wing remain more closely spaced buoying up the airplane. Raising the leading edge of the wing slightly (the angle of attack), increases the difference in pressure above and below the wing, adding more buoyancy.

Gravity This force pulls everything in the world to the ground and opposes lift. Therefore an airplane's center of gravity (the point at which an object balances) must coincide with the lift created by the wings. If it doesn't the airplane is unstable. With the center of gravity too far back the nose will pitch up; too far forward and the nose will pitch down.

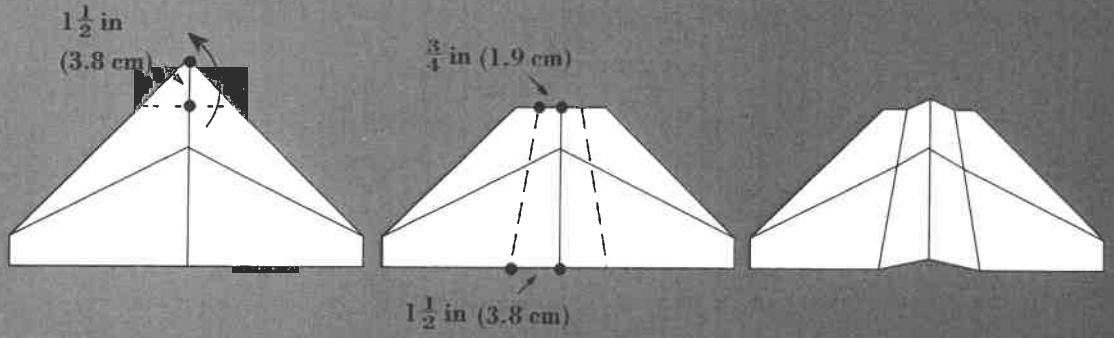
Making the Aero Bat



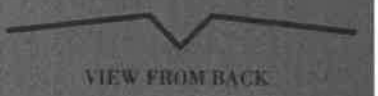
STEP 1 Lay the paper flat in a horizontal direction. Fold paper in half vertically, using the mountain fold. Unfold. Measure from upper edge and valley fold horizontally. Unfold. Then fold upper edge to meet horizontal crease. Refold original horizontal crease.

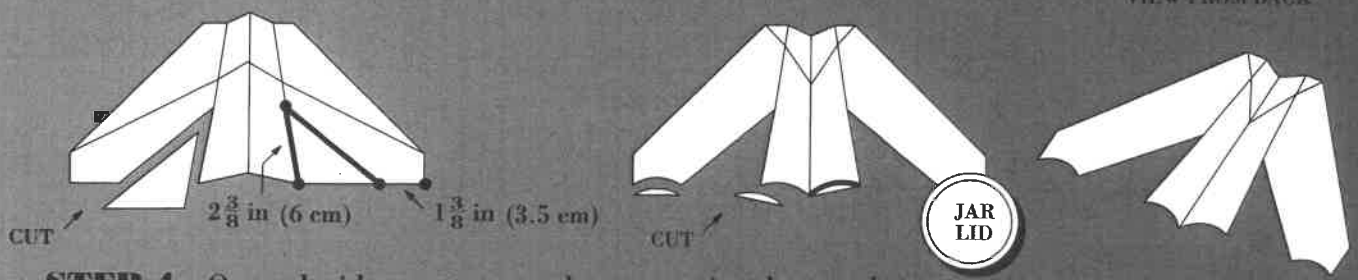


STEP 2 Valley fold upper corners to the vertical center crease. Unfold. Valley fold the upper corners to the diagonal creases. Then refold original diagonal creases.



STEP 3 Measure from tip and mountain fold horizontally. On each side, measure and valley fold, as shown.

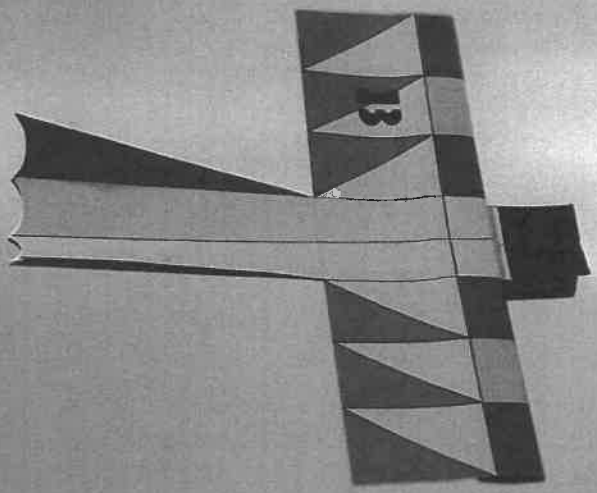


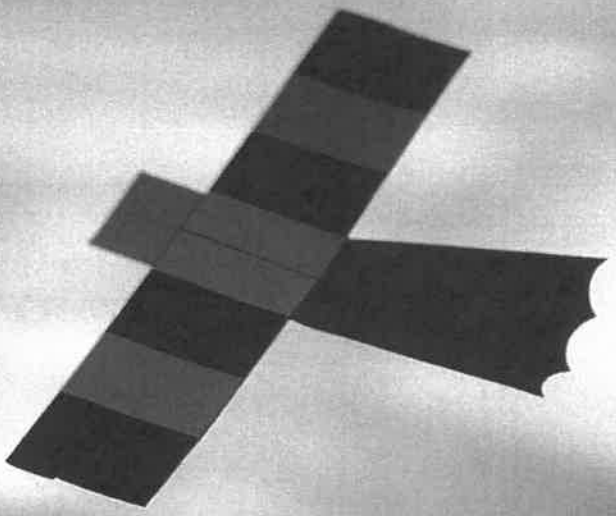


STEP 4 On each side, measure and cut out triangles, as shown. Flip the airplane over. Then, using a small jar lid, trace scalloped edges and cut out, as shown. Adjust folds so that viewed from the back the plane forms an inverted W.

AIRPLANE NUMBER TWO

Sky Bird





HISTORICAL INFORMATION

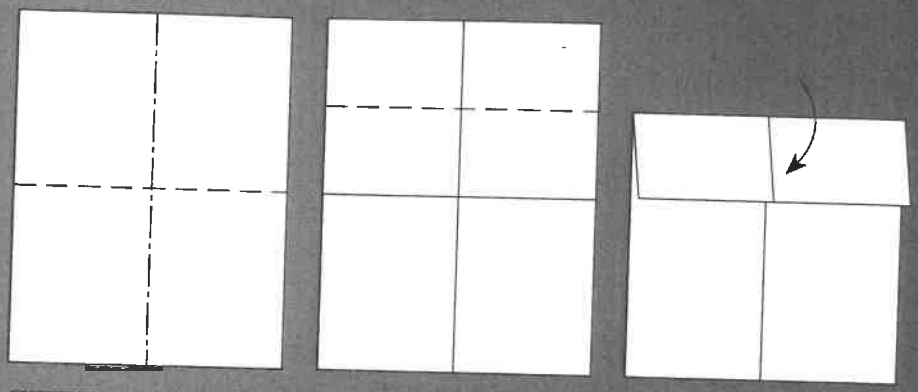
The first aircraft had no engines. They were gliders. Early airplane builders used high hills as launching points to test their constructions. The builders soon realized that in order for airplanes to fly successfully, having wings was not enough. Airplanes also needed horizontal and vertical surfaces for stability. Otto Lilienthal made many successful glider flights in the 1890s. This paper airplane is modeled on early glider aircraft.

Drag This is the force of resistance that air gives when objects move through it. Because of drag it is hard work to pedal your bike very fast. Drag also acts on an airplane in flight. It is responsible for slowing down a paper airplane.

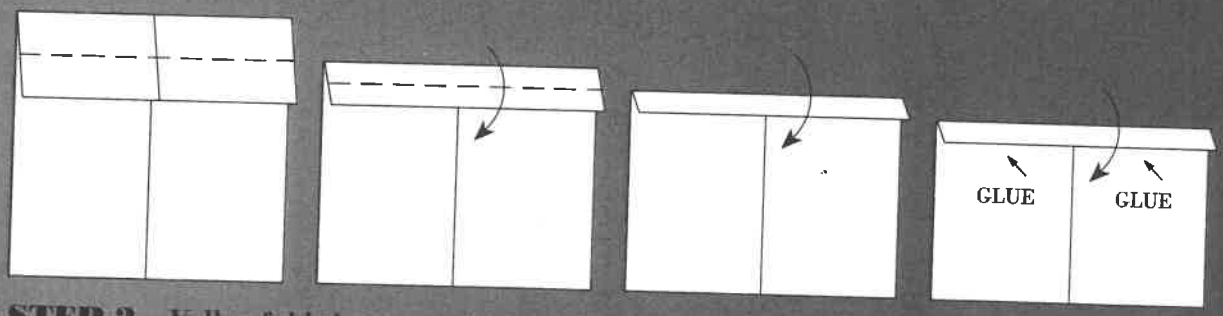
Thrust This is the forward momentum of an airplane. After you launch a paper airplane the force of lift prevents gravity from pulling the plane straight down, but gravity is still at work. In a glider, gravity provides thrust. In flight the nose should point down slightly. In gliding flight, gravity will pull the plane along an invisible mass of air in a gentle downward movement, just as gravity pulls a sled down a hill. If the nose is pointed down too much the plane will dive and crash into the ground.

The four forces – lift, gravity, thrust, and drag – are always present acting together on an airplane in flight.

Making the Sky Bird

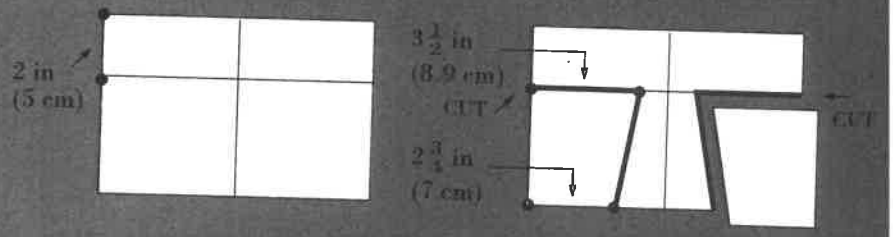


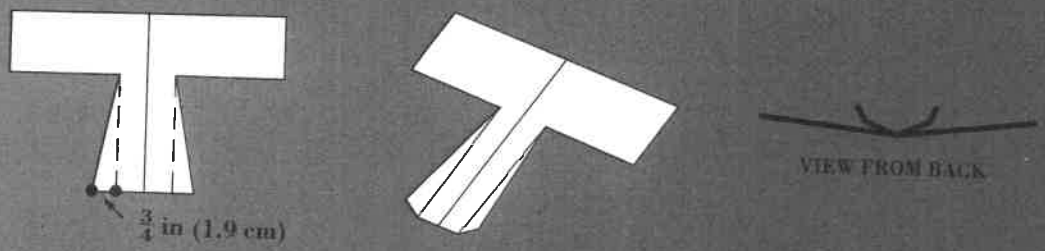
STEP 1 Lay paper flat in a vertical direction. Fold paper in half vertically using a mountain fold. Unfold. Valley fold the paper in half horizontally. Unfold. Then valley fold the top to meet the horizontal crease.



STEP 2 Valley fold the top again to meet the horizontal crease. Then valley fold top again, to meet the horizontal crease. Finally, applying glue to entire length, refold the original horizontal crease.

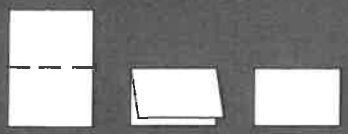
STEP 3 Flip over. Measure from top and draw line, as shown. On each side, measure and cut out along heavy lines to make wings and tail, as shown.





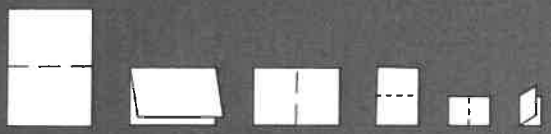
STEP 4 On each side of tail, measure and valley fold. Adjust dihedral (upward slanting of wings and tail), as shown.

STEP 5 Cut the two pieces left over from step 3 into rectangles, as shown.



STEP 6 To make the fuselage (body), valley fold piece A in half horizontally. Glue halves together.

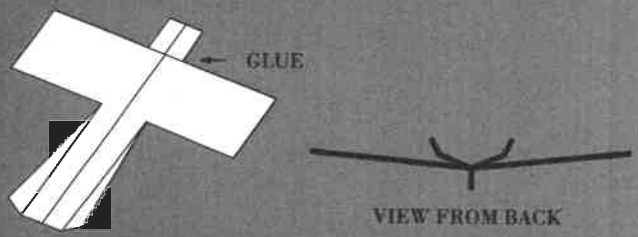
STEP 7 Valley fold this piece in half vertically. Then fold each vertical edge back to meet center crease. Glue center section. This is the fuselage.



STEP 8 To make nose ballast, valley fold piece B in half horizontally. Glue halves together. Valley fold in half vrtically. Glue halves together. Then valley fold in half horizontally. Glue halves together. Finally, valley fold in half vertically.

STEP 9 Glue this piece to the bottom of the center section of the fuselage, aligning at one of the ends. This end becomes the front.

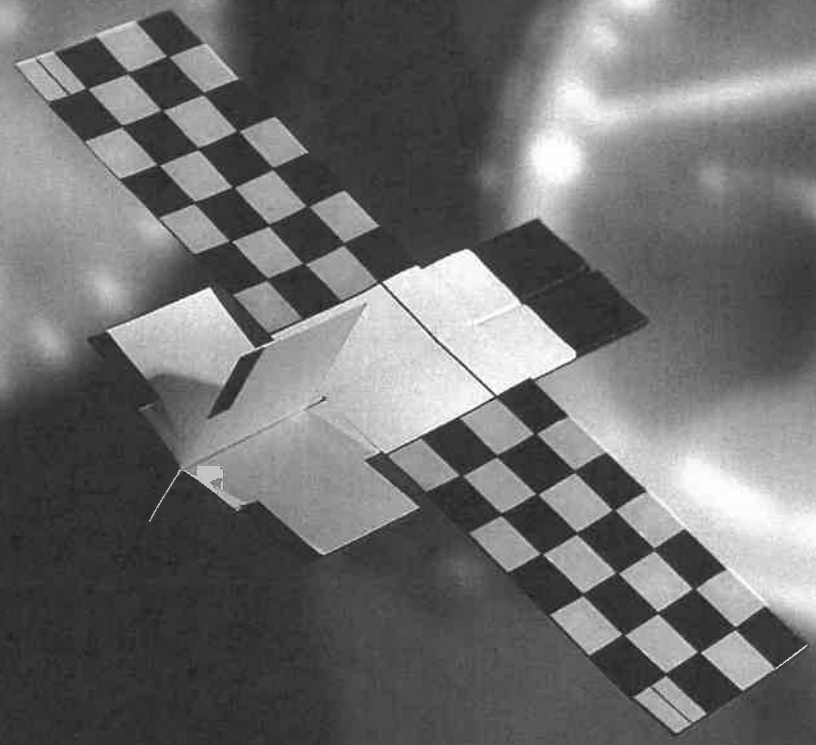
STEP 10 Measure from front of fuselage and mark the point, as shown.



STEP 11 Glue wings and tail to the fuselage with the leading edge (front of the wings)at the measured point. Make sure pieces are centered. Adjust dihedral (upward slanting of wings and tail) again.

AIRPLANE NUMBER THREE

Plain [illegible]



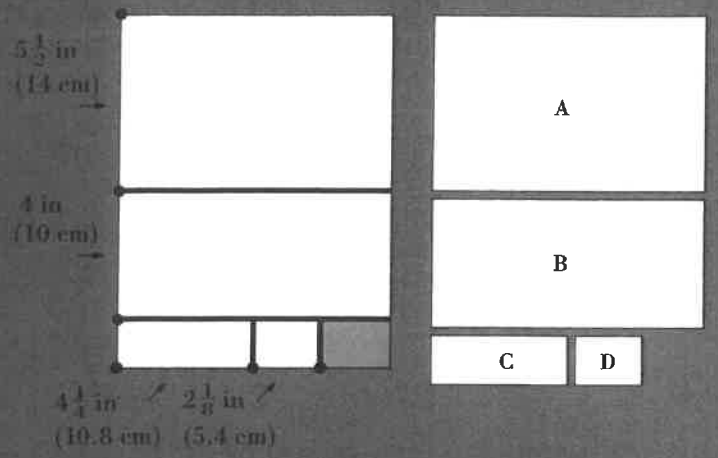
HISTORICAL INFORMATION

Achieving stability in flight was a major concern for early airplane designers, and remains so today. In the early days many different airplane shapes were tried. The most practical arrangement of parts had wings near the middle attached to a fuselage (body) with a tail at the back that had both horizontal and vertical surfaces. The fuselage also had room for the pilot. This arrangement has become the conventional and most often used aircraft design. Movable surfaces were added to the trailing (back) edges of wings and stabilizers: ailerons on the wing tips controlled roll (rotation along the length of an airplane), elevators on the horizontal tail controled pitch (nose up or down), and a rudder on the vertical tail controled yaw (nose left or right). This paper airplane is modeled on the conventional airplane.

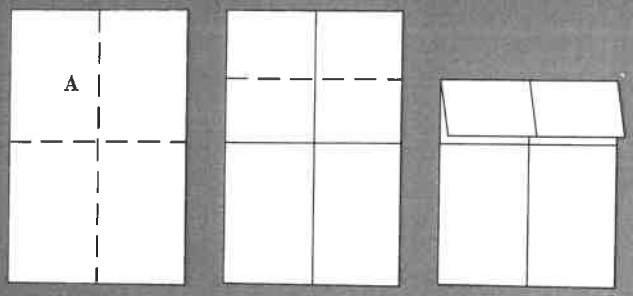
If an airplane is to be stable in flight, it is important t get the center of gravity in the correct spot. (The pla in this book are designed with the correct center of gravity location, but if more ballast is needed, add it the nose by using a small piece of paper, a dab of plasticine, some clear tape, or a small pin.) For best construction results use the 20 or 24 lb bond copier paper recommended, measure accurately, and make crisp folds. Use glue sparingly, but use enough to hol the parts together.

While an airplane is in flight the four forces (lift, gravi thrust, and drag) must be in balance. Then the airpla is in trim for straight and level flight. Paper airplanes need frequent small adjustments to the control surfac in order to fly well. You may need to make different t adjustments for indoor flight than for outdoor flight i lively air. Always make small corrections. Remember small adjustment has a big effect.

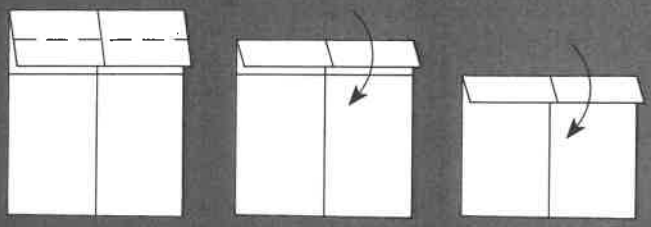
Making the Plain Plane



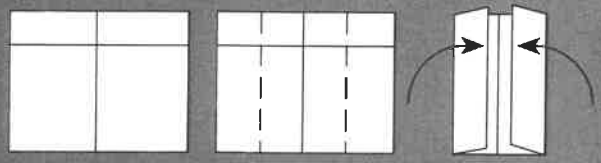
STEP 1 Measure and cut the various pieces from a sheet of bond paper, as shown.



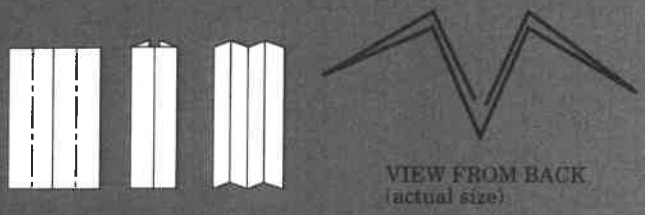
STEP 2 Lay piece A flat in a vertical direction. To make the fuselage, fold in half vertically using a valley fold. Unfold. Valley fold in half horizontally. Unfold. Then valley fold the top to meet the horizontal crease.



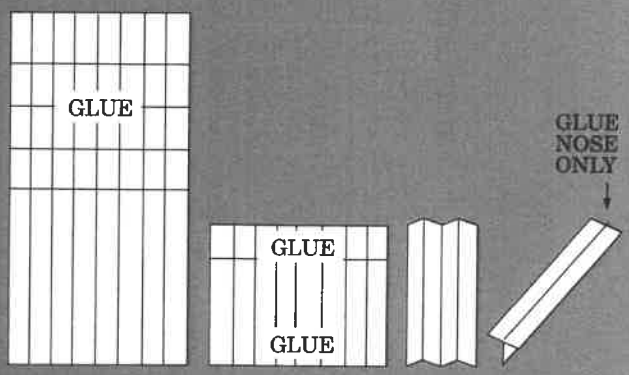
STEP 3 Valley fold the top again to meet the horizontal crease. Refold the original crease.



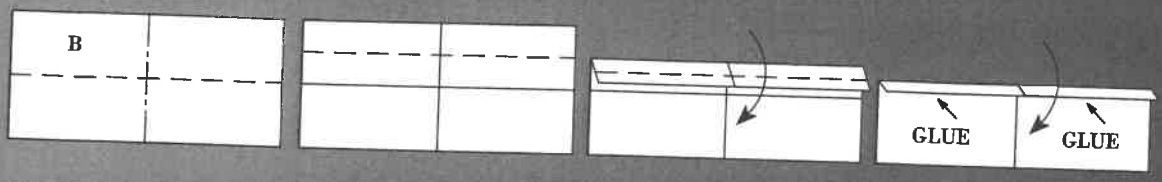
STEP 4 Valley fold each side so that outer edges meet center crease, as shown.



STEP 5 Fold each side again using a mountain fold, so that outer edges meet center crease at back. Then adjust folds so the paper looks like an upside-down W, as shown.

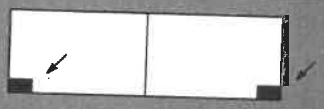


STEP 6 Unfold fuselage (piece A) completely. Refold applying glue to contacting surfaces, as shown. Make sure fuselage is straight.

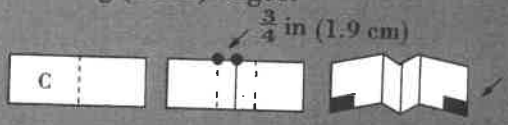


STEP 7 Use piece B to make the wings. Lay paper flat horizontally. Fold in half vertically, using a mountain fold. Unfold. Fold in half horizontally, using a valley fold. Unfold. Then valley fold so that top edge meets center crease. Fold again so that top edge meets center crease. Applying glue to entire length, refold original horizontal center crease. The folded over part is the bottom of the leading edge (front) of the wings.

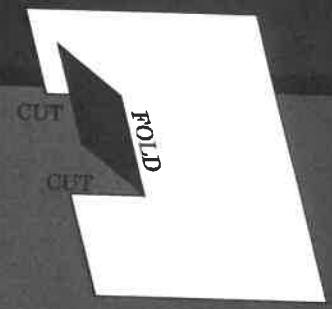
AILERONS
$\frac{3}{4}$ in x $\frac{1}{4}$ in
(1.9 cm x .6 cm)



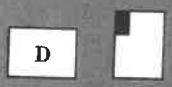
STEP 8 Make ailerons on trailing (back) edges.



ELEVATORS
$\frac{3}{4}$ in x $\frac{1}{4}$ in
(1.9 cm x .6 cm)



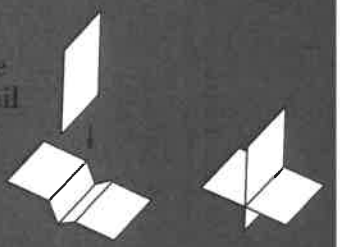
STEP 9 Use piece C to make the horizontal tail. Valley fold in half vertically. Unfold. On each side, measure from center crease, as shown, and mountain fold along dotted lines. Make elevators on trailing edges.

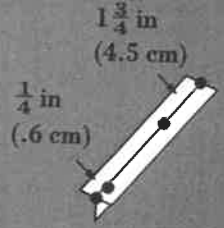


RUDDER
$\frac{3}{4}$ in x $\frac{1}{4}$ in
(1.9 cm x .6 cm)

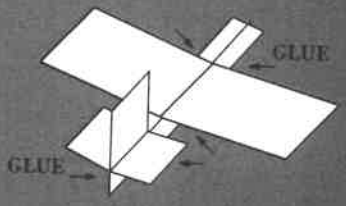
STEP 10 Use piece D to make the vertical tail. Make rudder on trailing (back) edge, as shown.

STEP 11 Apply glue to inside of horizontal tail and insert vertical tail, aligning trailing (back) edges.

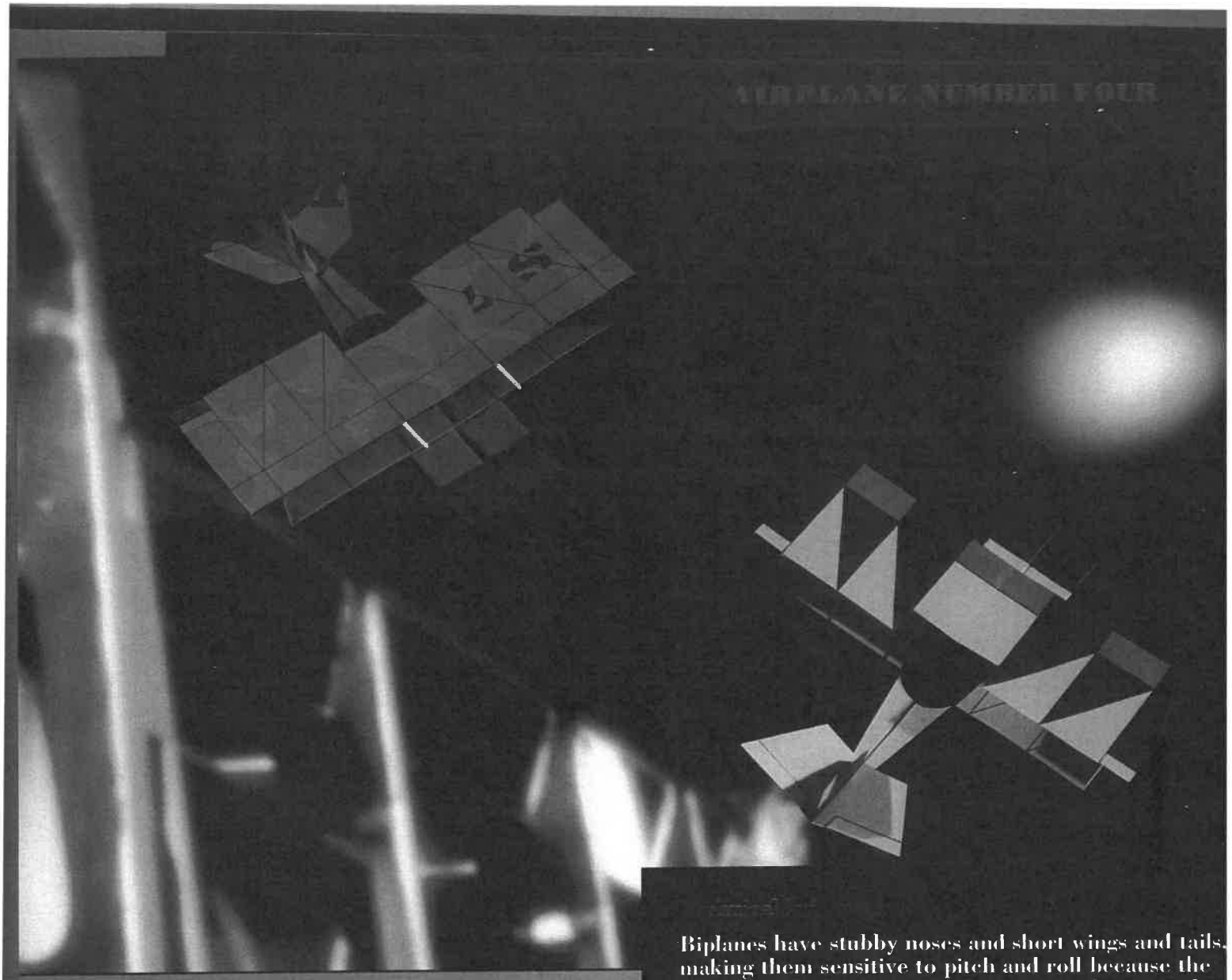




STEP 12 Measure and make marks for positioning tail and wings.



STEP 13 Applying glue, slide tail into fuselage. Then apply glue to wings and attach to fuselage. Adjust dihedral (upward slanting of wings and tail).



HISTORICAL INFORMATION

One way to improve lift without making large wings was by having two sets of them, one above the other (biplanes). The box-like construction of these airplanes made it easy to cross-brace the lightweight wooden frames with wire for strength. In 1903 Orville and Wilbur Wright put an engine into a biplane and became the first to attain sustained powered flight. Biplanes were used for most of the air battles of World War I, which began in 1914. Fighter biplanes were highly maneuverable although difficult to handle. Some examples are the Spad 7, Sopwith Camel, and Fokker 7. Biplanes are now used where small, durable, and maneuverable airplanes are required. Crop spraying is a good example. This paper airplane is modeled on early biplanes.

Biplanes have stubby noses and short wings and tails, making them sensitive to pitch and roll because the distances from the center of gravity to the control surfaces are small. The planes require careful trimmin

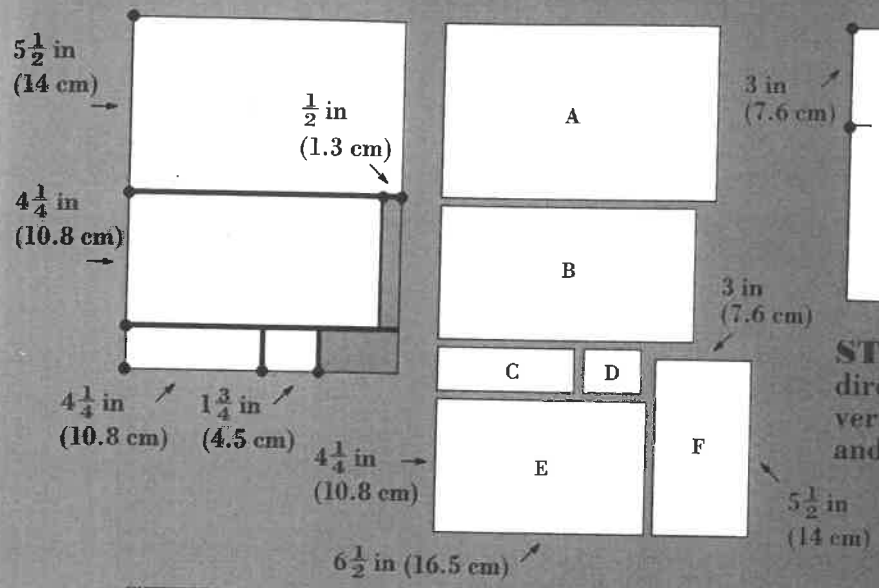
If the airplane zooms nose down to the ground, bend the elevators up slightly to raise the nose in flight.

This may cause the nose of the plane to pitch up sharpl As a result the air no longer flows smoothly over the wing surfaces but separates into eddies and the wings stall. To solve this problem bend the elevators up les

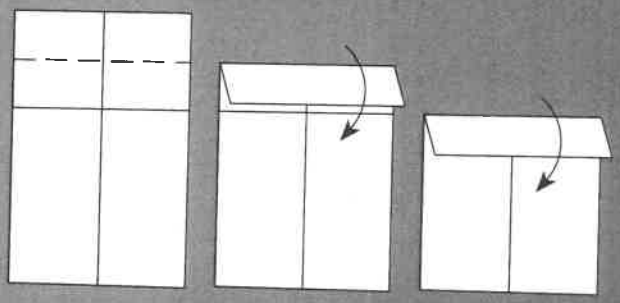
If the elevators are not bent at all and the nose still rises, don't bend the elevators down to correct the problem (a plane should never fly this way). Rather a a bit of extra ballast to the nose.

If the plane veers to left or right, bend the aileron up slightly on the wing that rises and down slightly on th wing that falls. Also bend the rudder on the vertical t slightly, opposite to the direction of the turn.

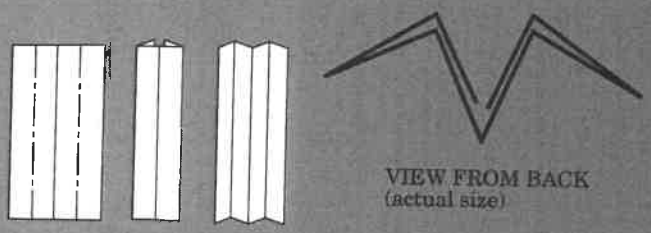
Making the Biplane



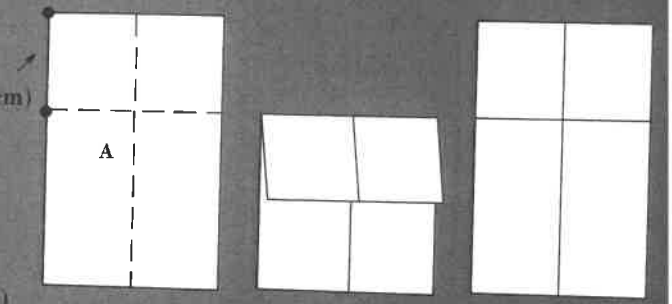
STEP 1 Measure and cut the various pieces from a sheet of bond paper, as shown. Two additional pieces E and F are needed, as shown.



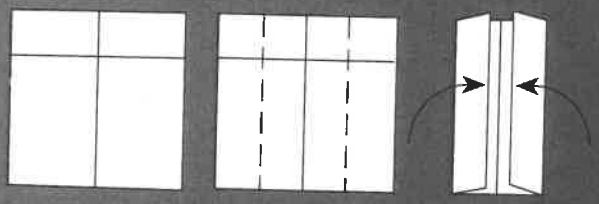
STEP 3 Valley fold the top to meet the horizontal crease. Then refold the original horizontal crease.



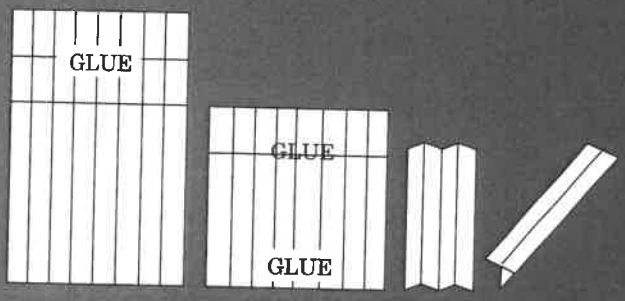
STEP 5 Fold each side again using a mountain fold, so that outer edges meet center crease at back. Then adjust folds so that paper looks like an upside-down W, as shown.



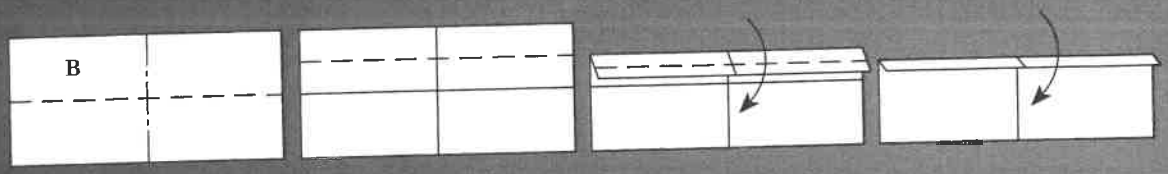
STEP 2 Lay piece A flat in a vertical direction. To make the fuselage, fold in half vertically using a valley fold. Unfold. Measure and valley fold horizontally, as shown. Unfold.



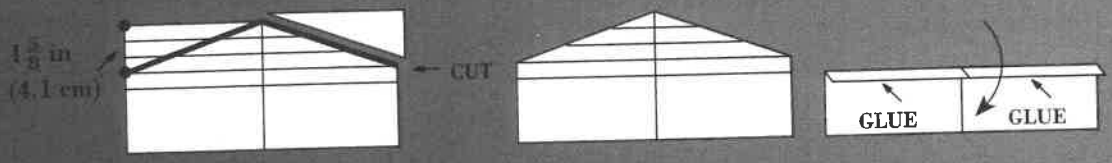
STEP 4 Valley fold each side so that outer edges meet center crease, as shown.



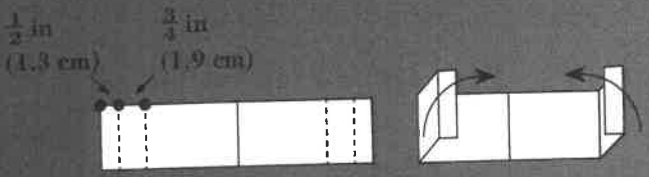
STEP 6 Unfold fuselage completely. Refold applying glue to all contacting surfaces, as shown. Make sure fuselage is straight. Do not glue nose yet.



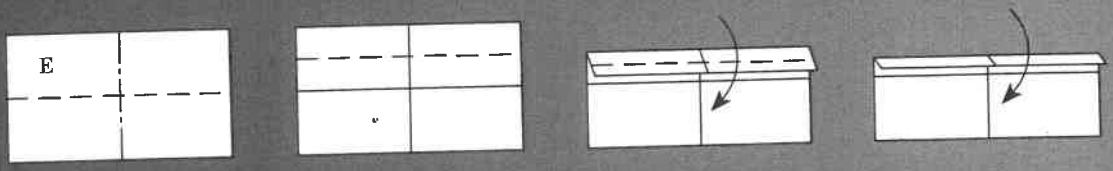
STEP 7 Lay piece B in a horizontal position to make the lower wings. Fold in half vertically, using a mountain fold. Unfold. Fold in half horizontally, using a valley fold. Unfold. Then valley fold so that top edge meets center crease. Fold again so that top edge meets center crease. Refold original horizontal center crease.



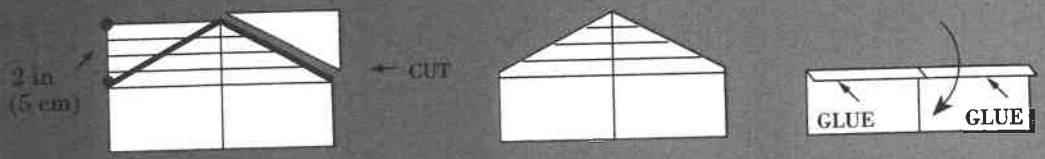
STEP 8 Unfold completely. On each side, measure and cut diagonally, as shown. Refold. Apply glue before refolding original horizontal center crease only. The folded over part is the bottom of the leading edge (front) of the wings.



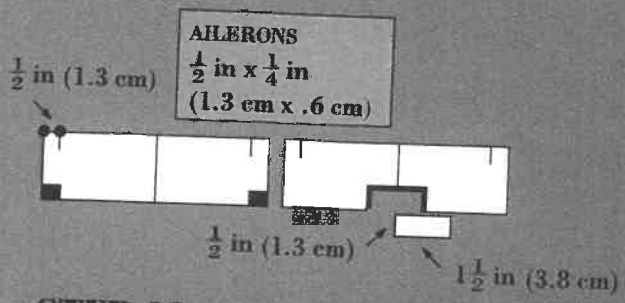
STEP 9 On each side, measure and valley fold, as shown.



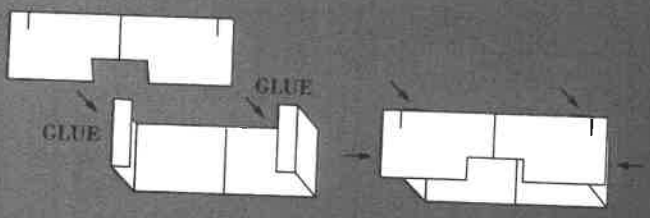
STEP 10 Lay piece E horizontally to make the upper wings. Fold in half vertically, using a mountain fold. Unfold. Fold in half horizontally, using a valley fold. Unfold. Then valley fold so that top edge meets center crease. Fold again so that top edge meets center crease. Refold original horizontal center crease.



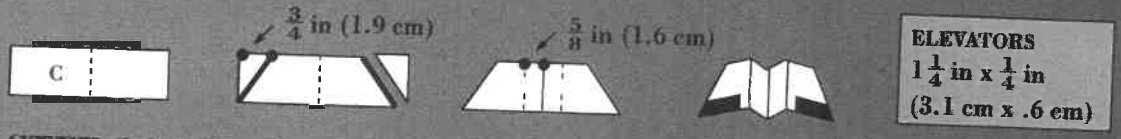
STEP 11 Unfold completely. On each side, measure and cut diagonally, as shown. Refold. Apply glue before refolding original horizontal center crease only. The folded over part is the bottom of the leading edge (front) of the wings.



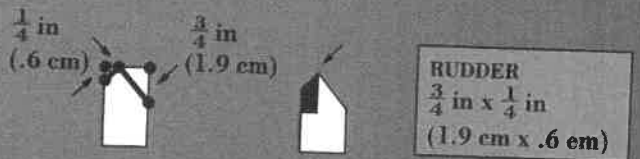
STEP 12 On each side of upper wings, measure from each wing tip and mark attachment points for lower wings, as shown. Cut out center piece on trailing edge, as shown. Make ailerons in locations indicated.



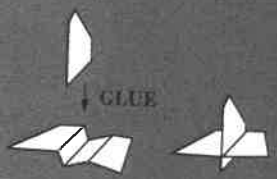
STEP 13 Applying glue, fasten upper and lower wings together, as shown. Make sure both leading edges face the same direction.



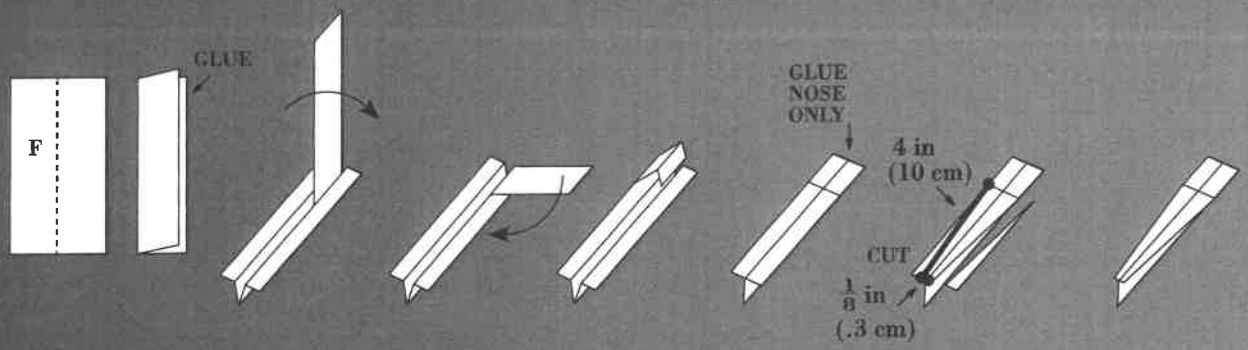
STEP 14 Use piece C to make the horizontal tail. Valley fold in half vertically. Unfold. On each side, measure from outer edges, as shown, and cut along heavy lines. Then, on each side, measure from center crease and mountain fold, as shown. Make elevators.



STEP 15 Measure and cut leading edge along heavy lines, as shown. On trailing edge, make rudder.

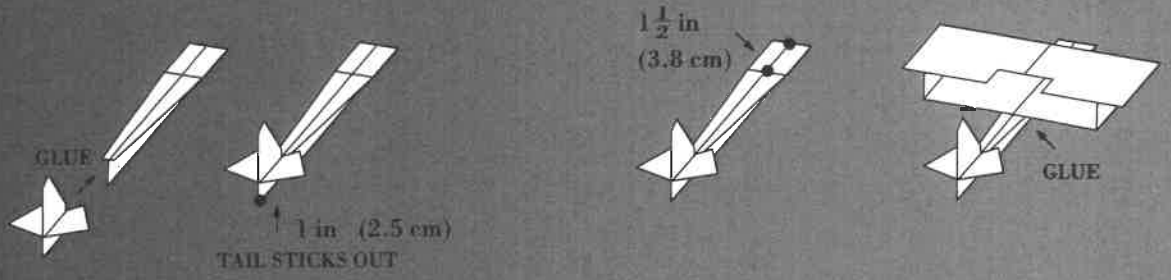


STEP 16 Apply glue to inside of horizontal tail and insert vertical tail, aligning trailing (back) edges.



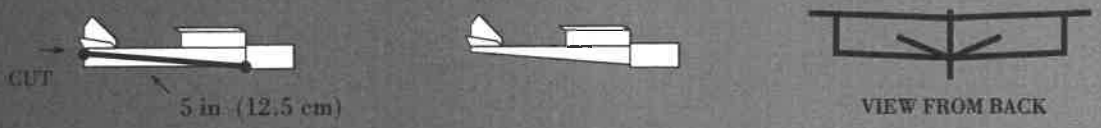
STEP 17 Use piece F to make the nose cowl (ballast). Valley fold piece in half vertically. Glue halves together. Applying glue to one side, insert F into nose and wrap entirely around fuselage, as shown. Then glue fuselage together at nose only.

STEP 18 On each side, measure and cut fuselage back along heavy lines, as shown.



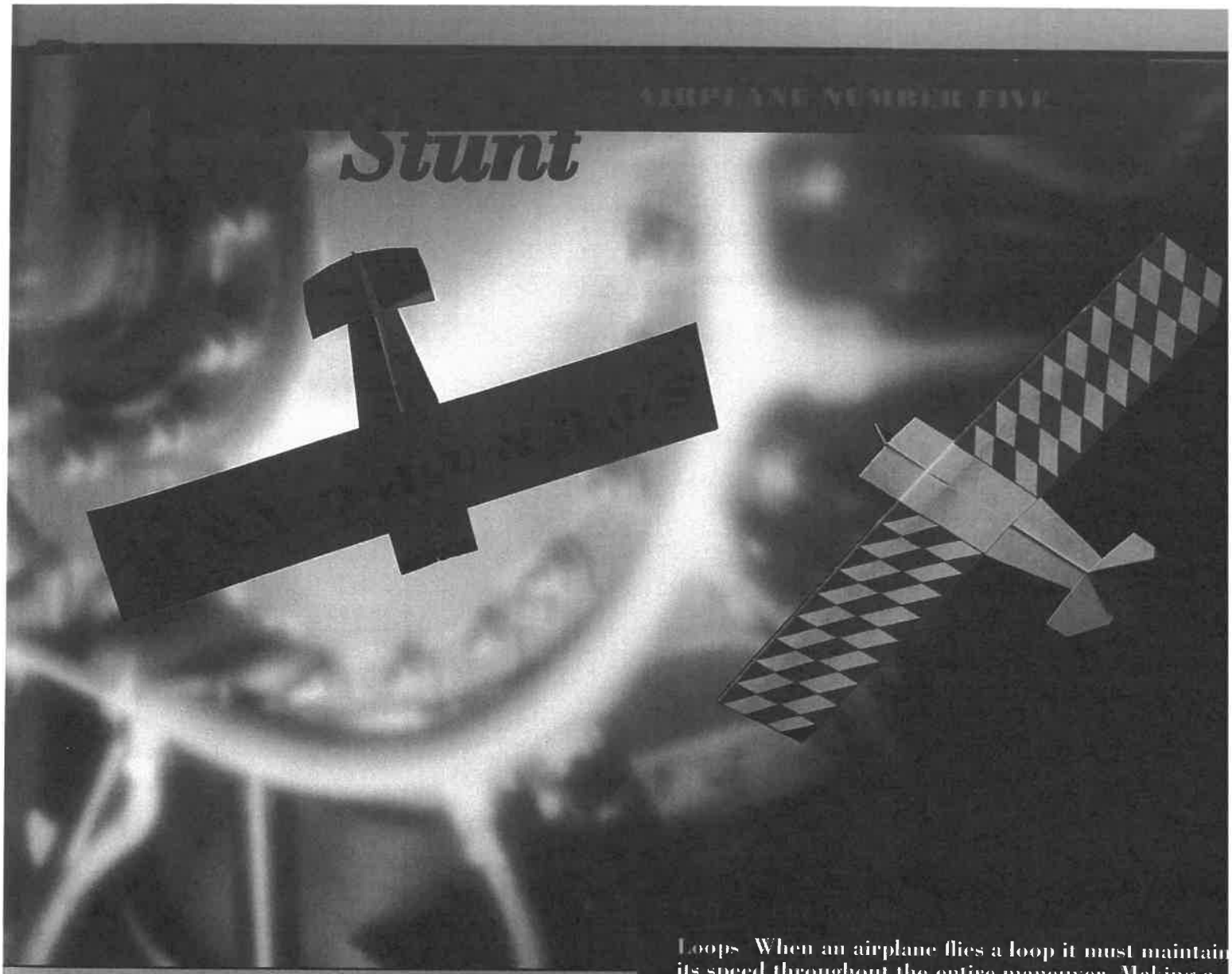
STEP 19 Applying glue, slide the tail into the back of the fuselelage.

STEP 20 Measure from front of fuselage and mark front of wing position. Glue wings in place, as shown.



STEP 21 Measure and cut back of fuselage, as shown. Adjust dihedral (upward slanting of wings and tail) to finish airplane.

Stunt



HISTORICAL INFORMATION

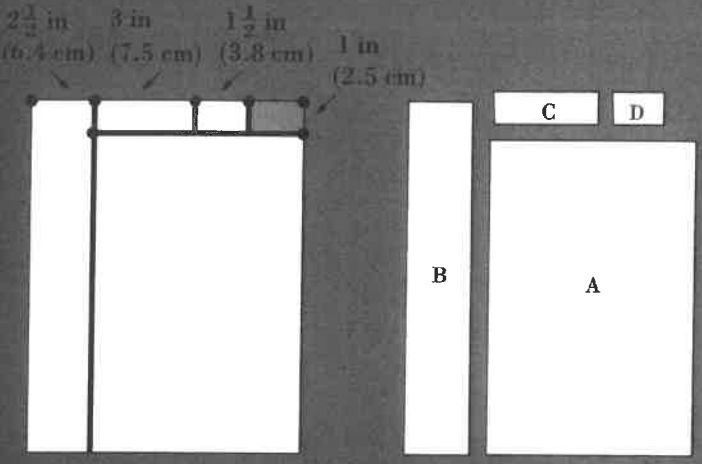
Ever since the earliest days of flight, flying events attracted great crowds of spectators. After World War I, many pilots performed aerial maneuvers learned in combat as stunts for entertainment. Sometimes people walked on the wings, or even jumped from one plane to another, while the airplanes were in flight. Such events (called barnstorming) thrilled spectators, and even today, air shows where aerobatics are performed, draw huge crowds. As planes improved, air racing became popular. Speeds exceeded 200 mph. This paper airplane is designed specifically to do stunts. It will not fly straight and level.

Loops When an airplane flies a loop it must maintain its speed throughout the entire maneuver. Making a round loop depends on centrifugal force. This force pushes the plane outwards, much like swinging a ball on a string. Only there is no string to hold it. Instead, the plane's wings create a centripedal force that keeps it from flying off and distorting the loop.

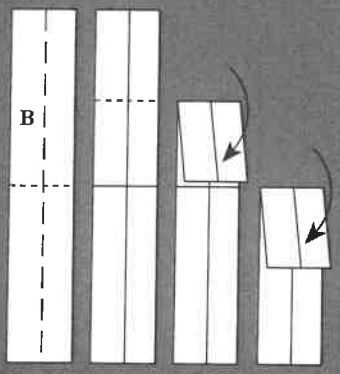
Rolls When the ailerons are used, one bends upward and the other one bends down. This causes the airplane to bank in the direction of the upward bent aileron. A powered airplane can roll completely, over and over, flying along in corkscrew fashion.

Hammerheads In this maneuver the airplane is flown straight up, but before it stalls the plane is turned so that it points straight down, swooping smoothly out of the dive.

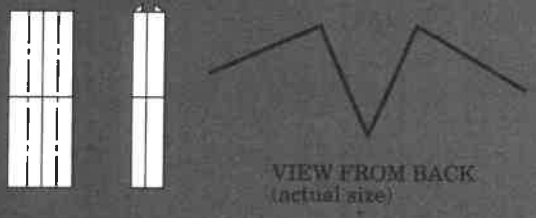
Making the Aero Stunt



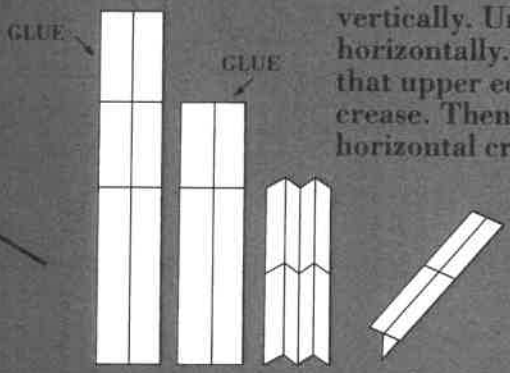
STEP 1 Measure and cut four pieces from a sheet of bond paper, as shown.



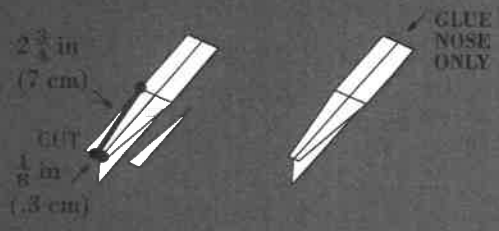
STEP 2 Lay piece B vertically to make the fuselage. Valley fold in half vertically. Unfold. Valley fold in half horizontally. Unfold. Valley fold so that upper edge meets the horizontal crease. Then refold the original horizontal crease.



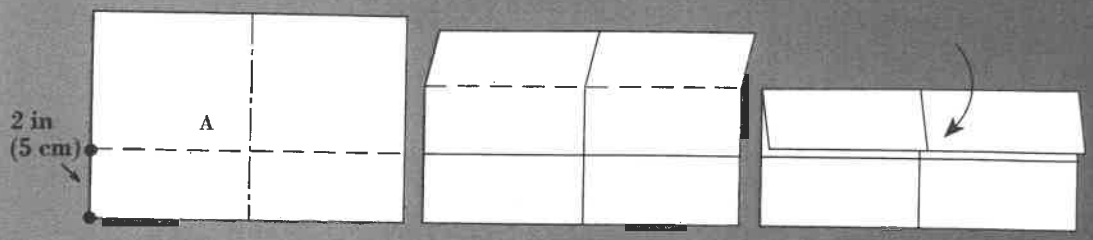
STEP 3 Fold each side using a mountain fold so that outer edges meet center crease at back. Then adjust folds so that paper looks like an upside-down W, as shown.



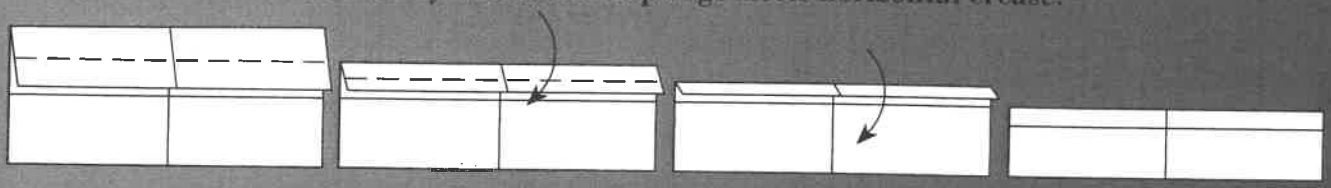
STEP 4 Unfold fuselage completely. Refold applying glue to all contacting surfaces, as shown. Make sure fuselage is straight.



STEP 5 On each side, measure and cut fuselage back along heavy lines, as shown. Then glue nose only.

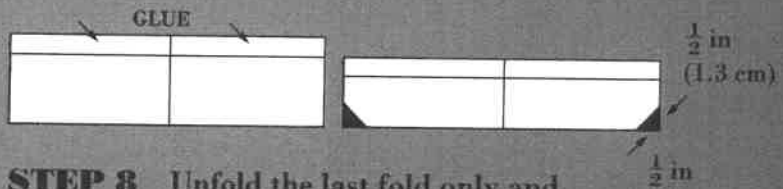


STEP 6 Lay piece A horizontally to make the wings. Fold in half vertically, using a mountain fold. Unfold. Measure from the bottom and fold horizontally, using a valley fold. Unfold. Then valley fold so that top edge meets horizontal crease.

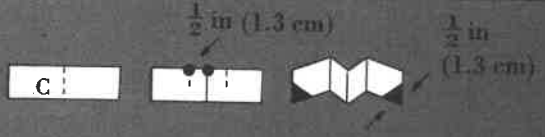


STEP 7 Valley fold so that top edge meets horizontal crease. Again valley fold so that top edge meets horizontal crease. Then refold original horizontal crease.

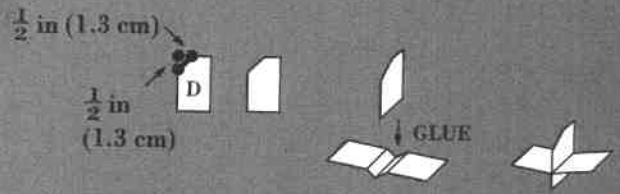
NOTE: Control surfaces for this plane are different from all the others.



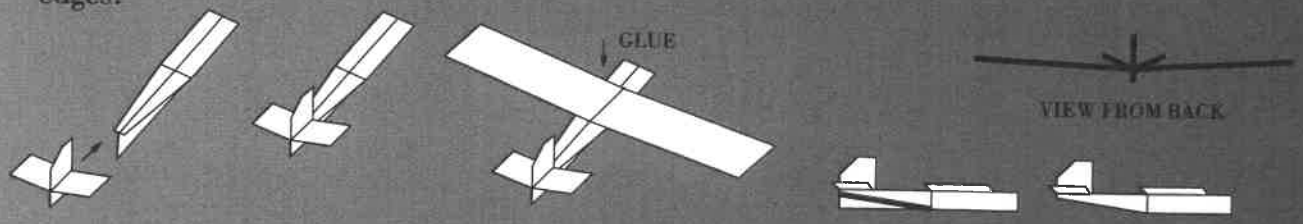
STEP 8 Unfold the last fold only and apply glue to entire length. Refold. Make ailerons by folding diagonally, as shown.



STEP 9 Use piece C to make the horizontal tail. Valley fold in half vertically. Unfold. On each side, measure from center crease and mountain fold, as shown. Make elevators by folding diagonally, as shown.



STEP 10 Use piece D for the vertical tail. Measure and cut diagonally along heavy line, as shown. Then apply glue to inside of horizontal tail and insert vertical tail, aligning trailing (back) edges.

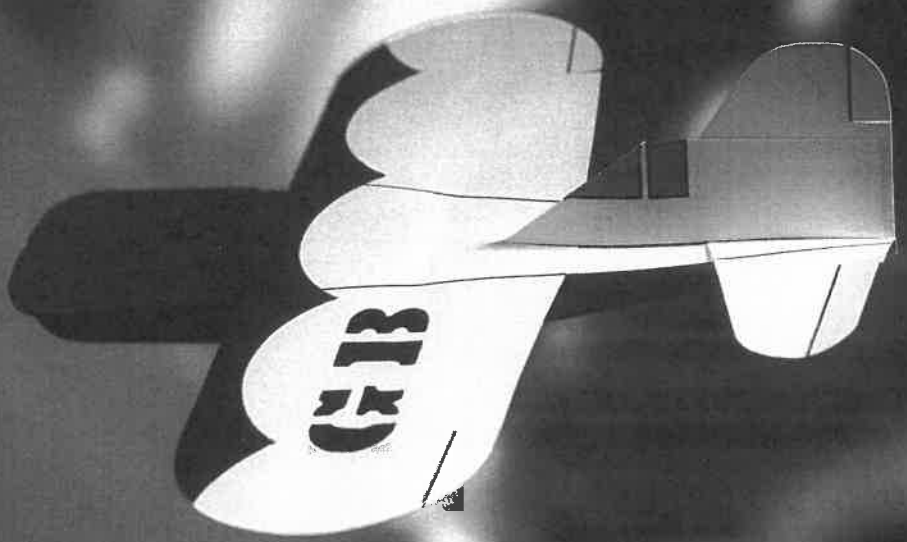


STEP 11 Applying glue, slide the tail into the back of fuselage, aligning trailing edges.

STEP 12 Applying glue, attach wings so that trailing edges align with seam on the fuselage.

STEP 13 Cut fuselage diagonally from the seam to the back, as shown by heavy line. Adjust dihedral (upward slanting of wings and tail), as shown.

Gee Bee Racer

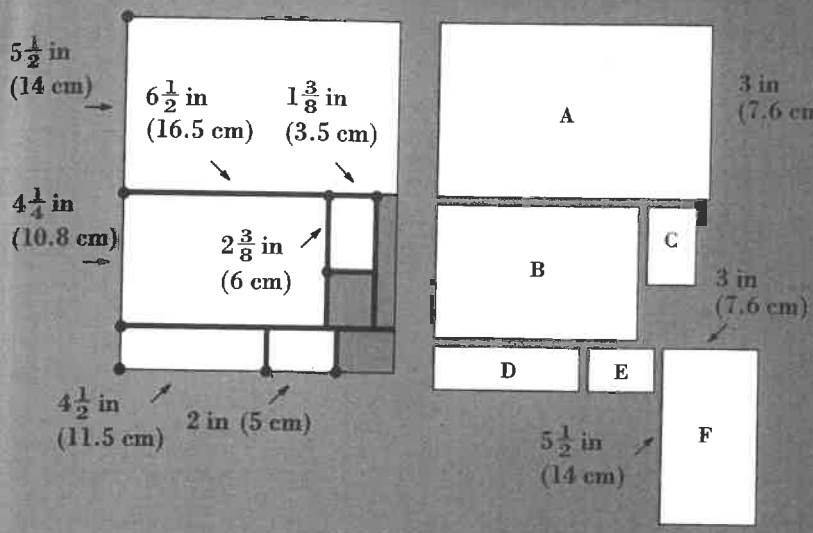


The Gee Bee model R is mostly a flying engine. Its big radial engine produces over 500 horsepower. Drag is the enemy of the racer. To go fast, even with a powerful engine, drag must be kept at a minimum. When this plane was being designed, different shapes were tested in a wind tunnel to find a shape that had the least amount of drag. A fat and stubby "teardrop" shape was found to be ideal. But such a stubby shape makes for a tempermental plane to fly. All airplanes that are stubby with short wings and tails are sensitive to pitch and roll because the distances from the center of gravity to the control surfaces are short. This paper model, however, is a remarkably good flyer.

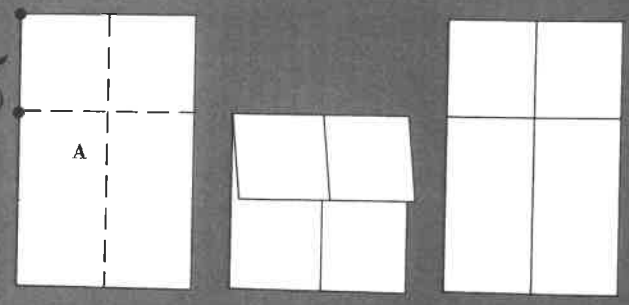
HISTORICAL INFORMATION

From the very beginning of powered flight, it became apparent that airplanes and speed belonged together. Air races were established so that builders could compete with one another. Three popular races were the Thompson Race, the Bendix Race, and the Shell Speed Dash. In 1932 the Granville brothers built the Gee Bee model R racer to compete in all three races. Two R models were built. That year they won the Thompson and set a new Speed Dash record of almost 300 mph. It takes great skill to fly at high speed near the ground in a tempermental airplane such as a racer. Both planes eventually crashed, and two pilots lost their lives. Today another Gee Bee, just like the originals, has been built. It is a popular attraction at many air shows.

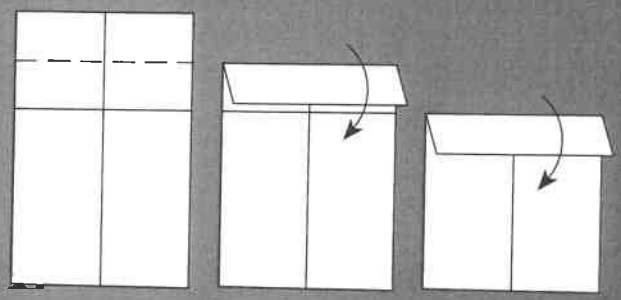
Making the Gee Bee



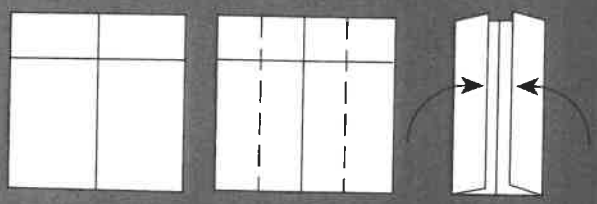
STEP 1 Measure and cut the various pieces from a sheet of bond paper, as shown. One additional piece F is needed, as shown.



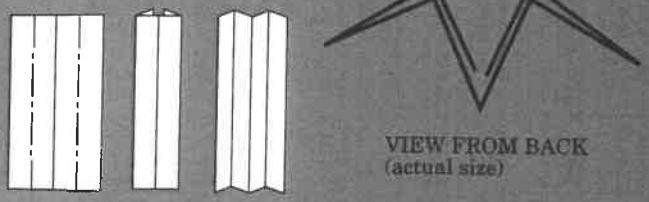
STEP 2 Lay piece A flat in a vertical direction. Fold in half vertically using a valley fold, to make the fuselage. Unfold. Measure and valley fold horizontally, as shown. Unfold.



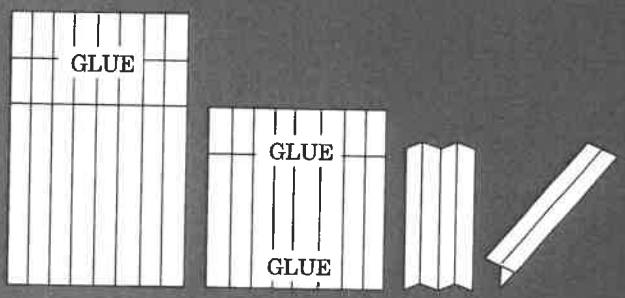
STEP 3 Valley fold the top to meet the horizontal crease. Then refold the original horizontal crease.



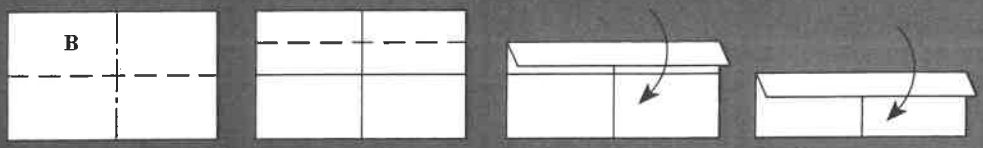
STEP 4 Valley fold each side so that outer edges meet center crease, as shown.



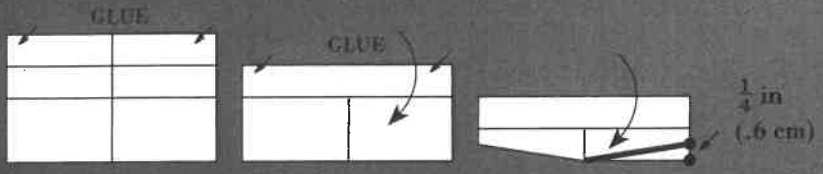
STEP 5 Fold each side again using a mountain fold, so that outer edges meet center crease at back. Then adjust folds so that paper looks like an upside-down W, as shown.



STEP 6 Unfold fuselage completely. Refold applying glue to all contacting surfaces, as shown. Make sure fuselage is straight. Do not glue nose yet.

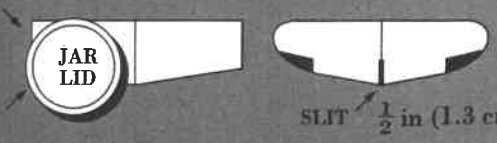


STEP 7 Lay piece B in a horizontal direction to make the wings. Fold in half vertically, using a mountain fold. Unfold. Fold in half horizontally using a valley fold. Unfold. Then valley fold again so that top edge meets center crease. Refold original horizontal center crease.



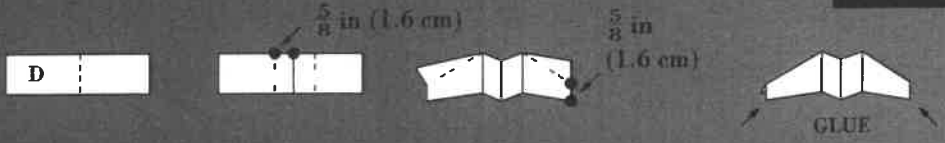
STEP 8 Unfold completely. Refold, applying glue to no more than 1 in (2.5 cm) from outer tips, as shown. The folded over part is the bottom of the leading edge (front) of the wings. Measure and cut trailing edges, as shown.

AILERONS
$\frac{3}{4}$ in x $\frac{1}{4}$ in
(1.9 cm x .6 cm)



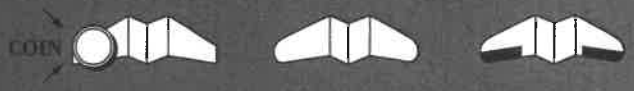
STEP 9 Trace around a small jar lid and cut out to round the wingtips. Make slit and ailerons, as shown.

NOTE: There are several planes that require rounded corners. These objects work well.

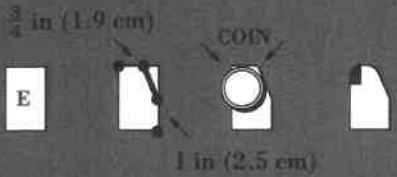


STEP 10 Use piece D to make the horizontal tail. Valley fold in half vertically. Unfold. On each side, measure from center crease and mountain fold, as shown. On each side, measure and mountain fold leading (front) edges, as shown. Glue.

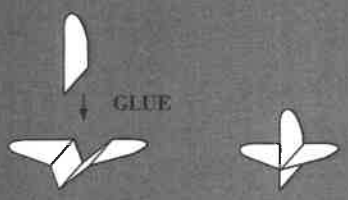
ELEVATORS
$1\frac{1}{4}$ in x $\frac{1}{4}$ in
(3.1 cm x .6 cm)



STEP 11 Trace around a coin and cut out to make rounded outer corners. Make elevators in locations shown.

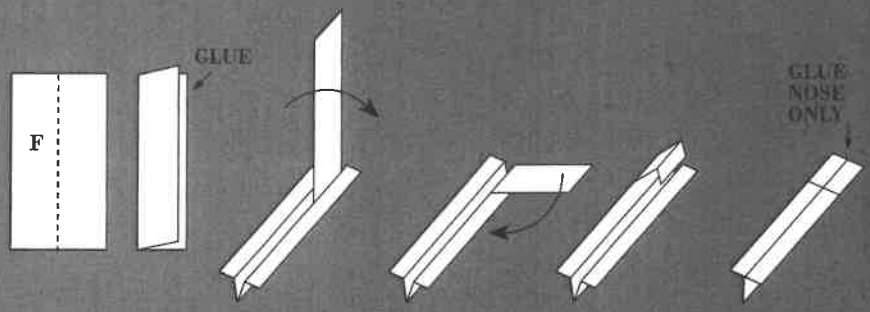


RUDDER
$\frac{1}{2}$ in x $\frac{1}{4}$ in
(1.3 cm x .6 cm)

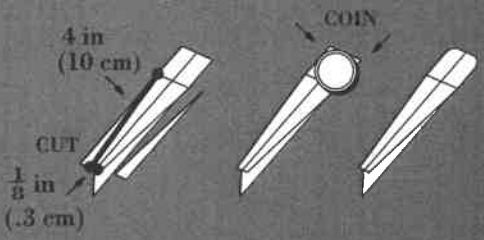


STEP 12 Use piece E to make the vertical tail. Measure and cut leading (front) edge as shown by heavy line. Trace around a coin and cut out to round corners. On trailing edge, make rudder.

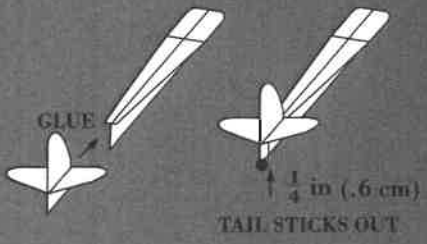
STEP 13 Apply glue to inside of horizontal tail and insert vertical tail, aligning trailing (back) edges.



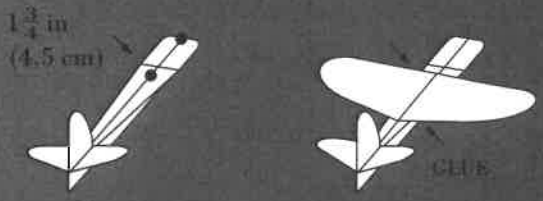
STEP 14 Use piece F to make the nose cowl (ballast). Valley fold piece in half vertically. Glue halves together. Applying glue to one side, insert F into nose and wrap entirely around fuselage, as shown. Then glue fuselage together at nose only.



STEP 15 On each side, measure and cut fuselage back along heavy lines, as shown. Trace around a coin and cut out to round the nose.

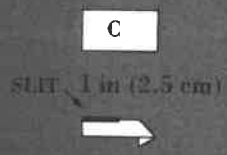


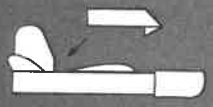
STEP 16 Applying glue, slide the tail into the back of the fuselage.

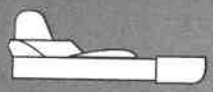


STEP 17 Measure from front of fuselage and mark front of wing position. Glue wings in place, as shown.

CANOPY (type 1)
$1\frac{3}{8}$ in x $2\frac{3}{8}$ in (3.5 cm x 6 cm)
Top point 1 in (2.5 cm)





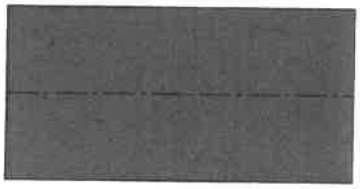


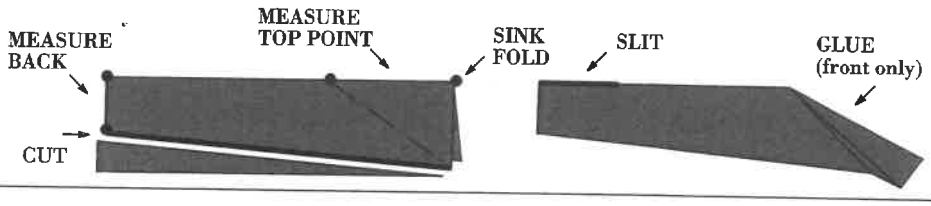
STEP 18 Make the canopy, using piece C (see below). Make a slit at the center back, as shown.

STEP 19 Apply glue to the inside back and front tab of the canopy. Insert tab into the fuselage, sliding the vertical tail into the slit.

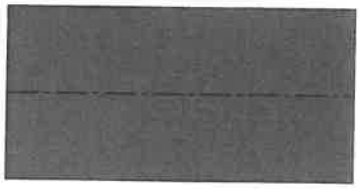
STEP 20 Measure and cut back of fuselage, as shown. Adjust dihedral (upward slanting of wings and tail) to finish airplane.

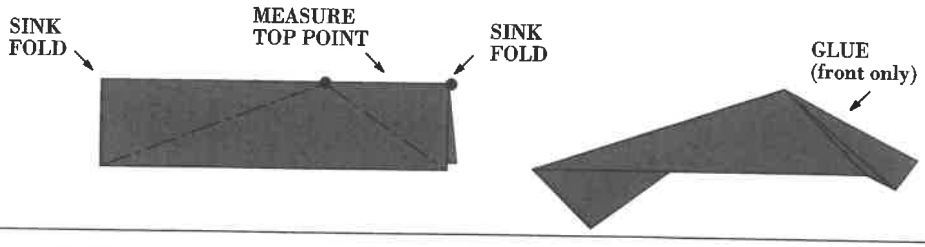
Type 1





Type 2

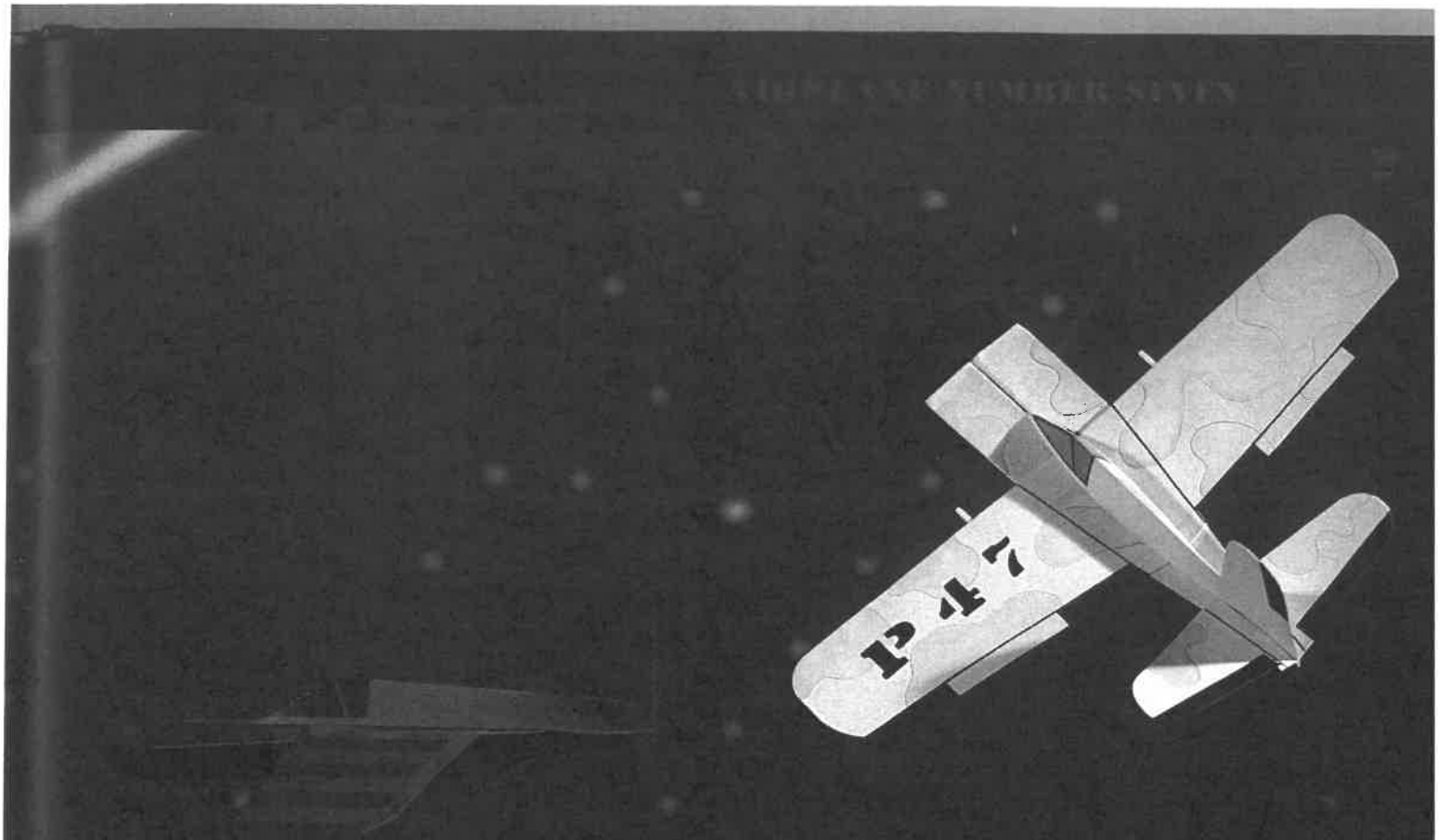




(a) Measure and cut paper to dimensions specified for the particular airplane. Lay paper flat in a horizontal direction. Fold in half horizontally, using a mountain fold.

(b) With the paper folded in half as in step (a), measure top point and draw lines. For type 1, sink-fold (see p 6) the front corner and cut on heavy line. For type 2, sink fold front and back corners.

(c) Press flat to finish the canopy. Only the front end should be glued.



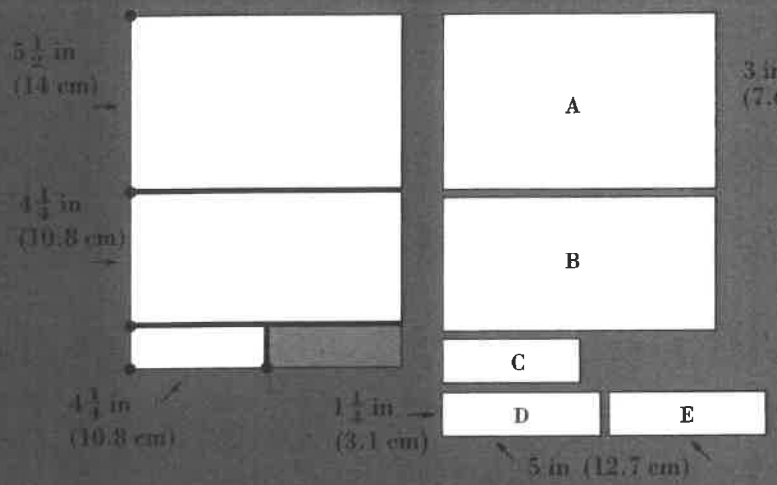
HISTORICAL INFORMATION

With the outbreak of another world war in 1939, there was again a demand for maneuverable fighter planes. Streamlined airframes capable of great speed were designed. More powerful engines were made, pushing speeds past 400 mph. Some popular examples of fighters are the Republic P47, North American P51, Supermarine Spitfire, Messerschmitt ME109, and the Mitsubishi "Zero". After the war ended in 1945 some of these warplanes became sport planes, and these inspired the building of aircraft using aerodynamic and technical information gained from fighter design. This paper airplane is modeled on the fighters of World War II and present-day sport planes.

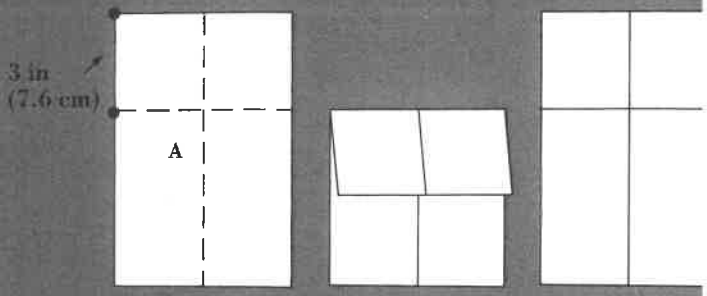
Speed and Drag: From the very beginning of powered flight it was realized that speed and flight belonged together. The unobstructed freedom that flying offered, combined with speed, made it easy and fast to get from place to place. The biplanes of World War I, with engines about as powerful as those found in a small car, could exceed 100 mph. The fighters of World War II, with much more powerful engines, could exceed 400 mph. With such an increase in speed, drag also increased and airplane builders had to find ways to reduce it as much as possible. One way was by rounding corners and removing things that stuck out into the airflow (streamlining) and hiding them underneath a smooth skin.

In slow flight (as in landing) airplanes that can fly fast need a method of increasing the lift of their high-speed wings. They have secondary control surfaces, called flaps, that bend down on the trailing edges of the wings near the fuselage. Flaps are used not only when landing but also for takeoff or whenever extra lift is needed.

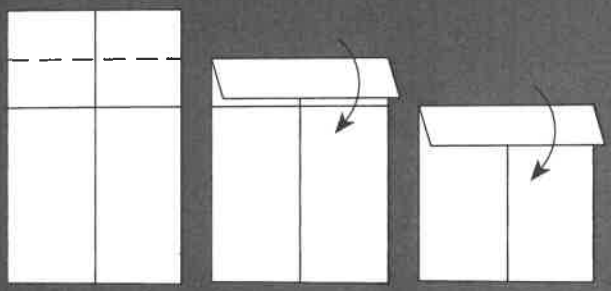
Making the P47



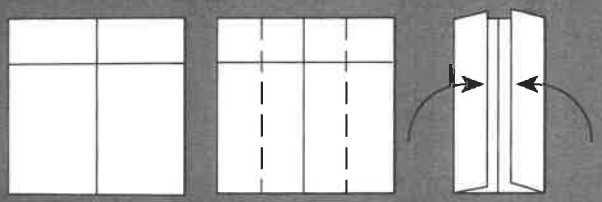
STEP 1 Measure and cut the various pieces from a sheet of bond paper, as shown. Two additional pieces D and E are needed, as shown.



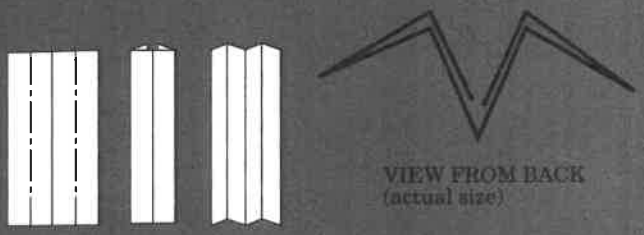
STEP 2 Lay piece A flat in a vertical direction to make the fuselage. Fold in half vertically using a valley fold. Unfold. Measu and valley fold horizontally, as shown. Unfo



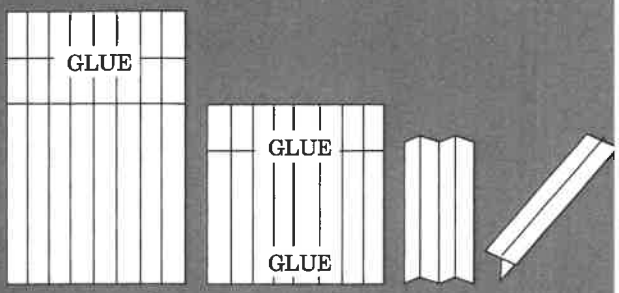
STEP 3 Valley fold the top to meet the horizontal crease. Then refold the original horizontal crease.



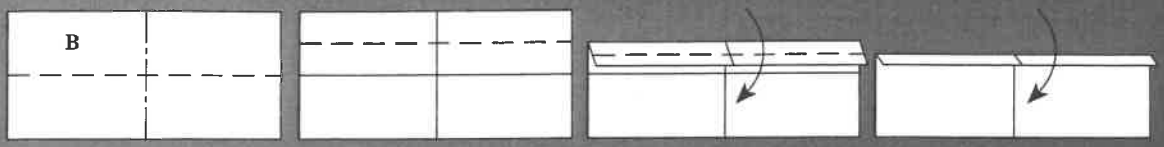
STEP 4 Valley fold each side so that outer edges meet center crease, as shown.



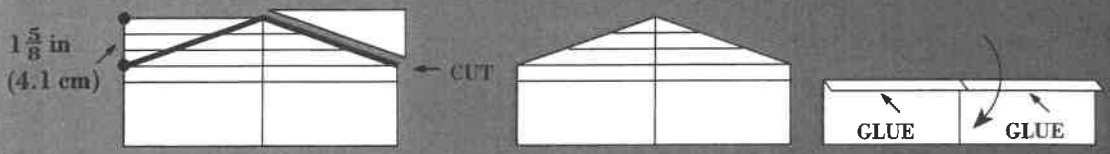
STEP 5 Fold each side again using a mountain fold, so that outer edges meet center crease at back. Then adjust folds so that paper looks like an upside-down W, as shown.



STEP 6 Unfold fuselage completely. Refold applying glue to all contacting surfaces, as shown. Make sure fuselage is straight. Do not glue nose yet.



STEP 7 Lay piece B horizontally to make the wings. Fold in half vertically, using a mountain fold. Unfold. Fold in half horizontally, using a valley fold. Unfold. Then valley fold so that top edge meets center crease. Fold again so that top edge meets center crease. Refold original horizontal center crease.



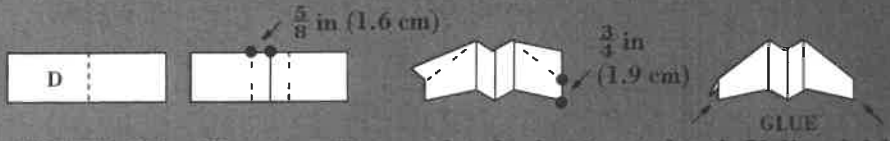
STEP 8 Unfold completely. On each side, measure and cut diagonally, as shown. Refold. Apply glue before refolding original horizontal center crease only. The folded over part is the bottom of the leading edge (front) of the wings.

STEP 9 Measure and cut trailing edge (back) of wings, as shown. Trace around a coin to make rounded corners at the leading edges and a small jar lid for the trailing edge, and cut out (see p 26). Make ailerons, as shown.

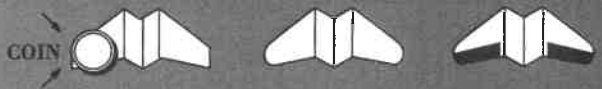
AILERONS
1 in x 1/4 in
(2.5 cm x .6 cm)

NOTE: In the instructions, secondary control surfaces (flaps) are shown in red.

STEP 10 On trailing edges, make ailerons. Then make secondary control surfaces (flaps), in locations shown.

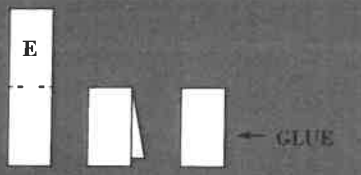


STEP 11 Use piece D to make the horizontal tail. Valley fold in half vertically. Unfold. On each side, measure from center crease, as shown, and mountain fold. On each side, measure and mountain fold leading (front) edges, as shown. Glue.

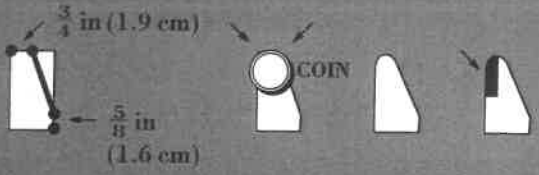


ELEVATORS
1 1/2 in x 1/4 in
(3.8 cm x .6 cm)

STEP 12 Trace around a coin and cut out to make all the corners rounded (see p 26). Make elevators, as shown.

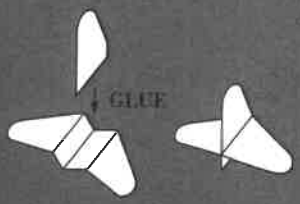


STEP 13 Use piece E to make the vertical tail. Mountain fold in half horizontally, glue halves together.

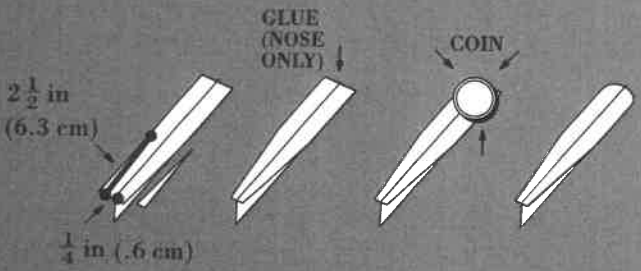


RUDDER
$\frac{3}{4}$ in x $\frac{1}{4}$ in
(1.9 cm x .6 cm)

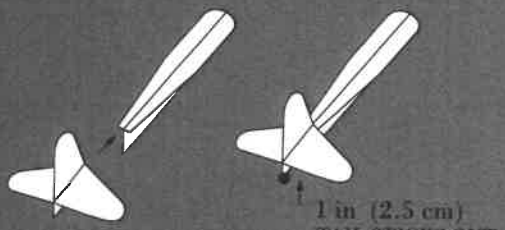
STEP 14 Measure and cut leading edge along heavy line, as shown. Trace around a coin and cut out to roun corners (see p 26). On trailing (back) edge, make rudde



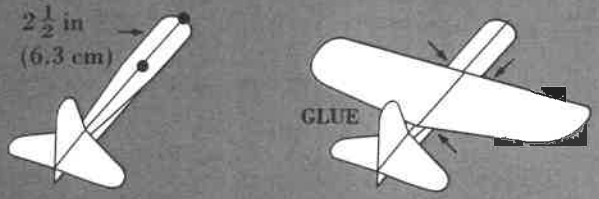
STEP 15 Apply glue to inside of horizontal tail and insert vertical tail, aligning trailing (back) edges.



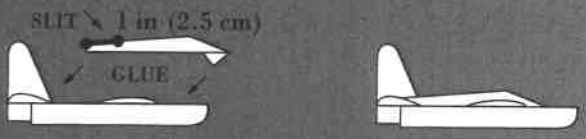
STEP 16 On each side, measure and cut fuselage ba as shown. Then glue nose only. To round corners, trace around a coin and cut out all corners of the nose (see p 2



STEP 17 Applying glue, slide the tail into back of fuselage.

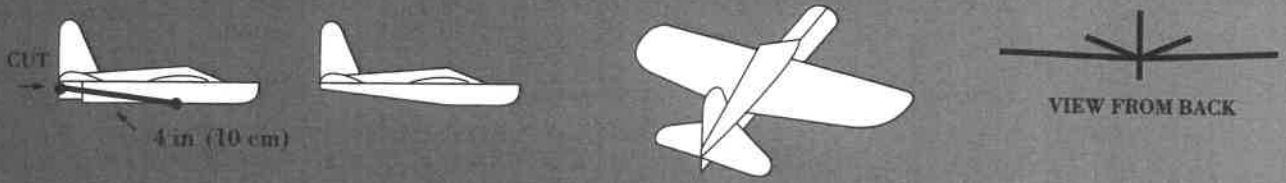


STEP 18 Measure from front of fuselage and glue wings in place, as shown.



CANOPY (type 1)
$1\frac{1}{4}$ in x $4\frac{1}{4}$ in (3.1 cm x 10.8
Top point 1 in (2.5 cm)
Back $\frac{3}{8}$ in (1 cm)

STEP 19 Make a type 1 canopy, using piece C (See p 28). Cut slit in back of canopy. Apply glue to inside back of canopy and the front tab. Slip back over vertical tail and front tab into fuselage, as shown.



STEP 20 Measure and cut back of fuselage along heavy line, as shown. Adjust dihedral (upward slanting of wings and tail), as shown.

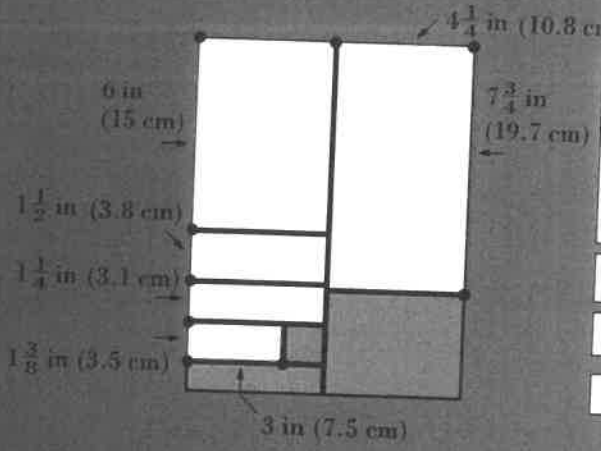
HISTORICAL INFORMATION

Beyond a certain speed conventional airplanes become less controllable and propellers lose their efficiency. When aircraft approach the speed of sound (about 760 mph) their control becomes unpredictable due to air resistance. For high speed flight a new shape of airplane was needed. For propulsion, designers turned to rockets and jets, which don't need propellers. In the quest for greater speed, Messerschmitt experimented with a rocket propelled airplane during the war, the ME163. After the war, deHavilland used the information gained to build the similar, but jet engined, experimental DH108 Swallow. It had wings that swept back and no horizontal stabilizers. In 1946 it flew over 600 mph. This paper airplane is modeled on the deHavilland Swallow.

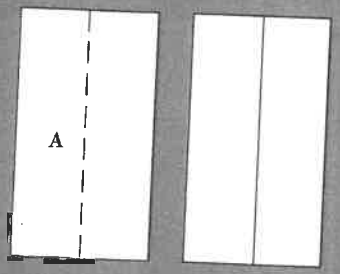
Sweepback: Every increase in speed increases drag. Below a speed of about 250 mph air molecules easily move around a well streamlined airplane's surfaces. As speed is increased, however, the molecules cannot move out of the way quickly enough and their resistance piles them up into a pressure ridge ahead of the wings, something like a snowplow pushing snow. This build-up of pressure (drag) makes it difficult to fly the airplane, and at the speed of sound it can become dangerous. Sweeping the wings back away from the fuselage and making them broader delayed the pressure build-up until a greater speed was reached. This resulted in wings that maintain their efficiency, safely allowing planes to fly faster.

The experimental Swallow was built to test high speed flight. But even with swept-back wings, when this plane reached the speed of sound, the pressure build-up was great enough to break the airplane, and it crashed.

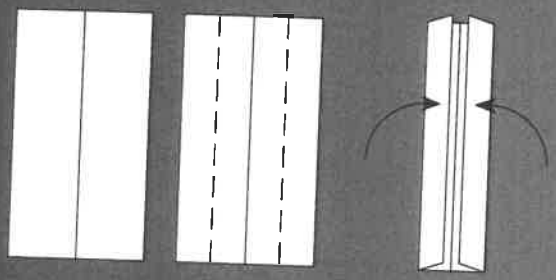
Making the DH 108



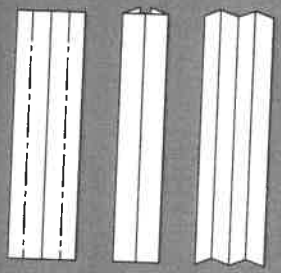
STEP 1 Measure and cut the various pieces, as shown.



STEP 2 Lay piece A fla a vertical direction. To ma the fuselage, fold in half vertically using a valley fol Unfold.

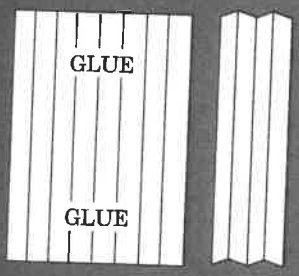


STEP 3 Valley fold each outer edge to meet center crease, as shown.

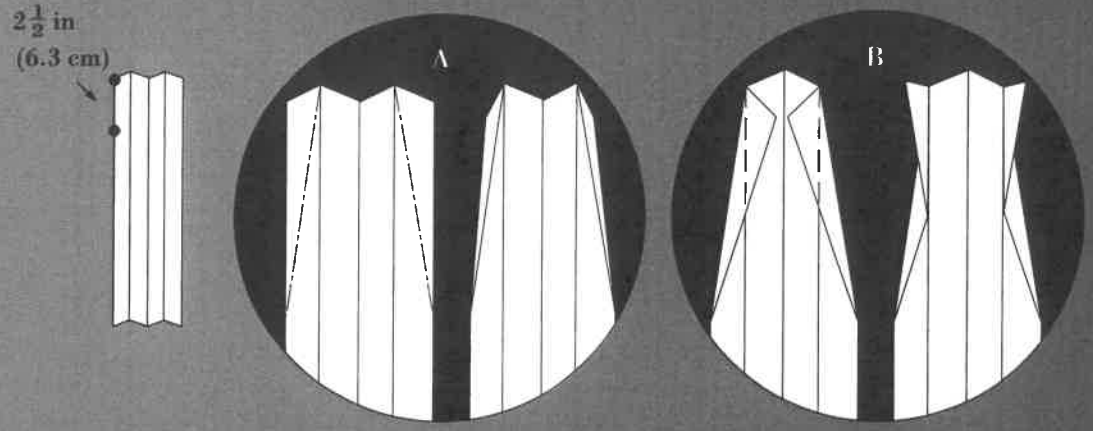


VIEW FROM BACK
(actual size)

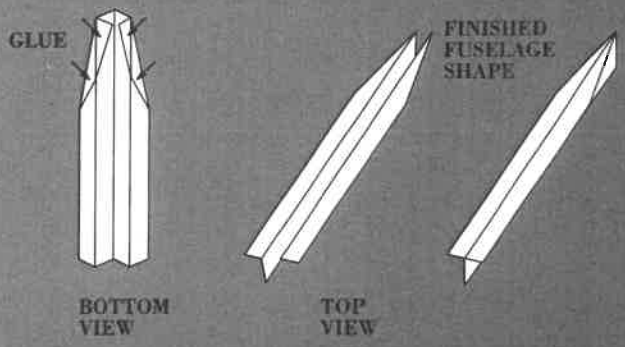
STEP 4 Fold each side again using a mountain fold, so that outer edges meet center crease at back. Then adjust folds so that paper looks like an upside-down W, as shown.



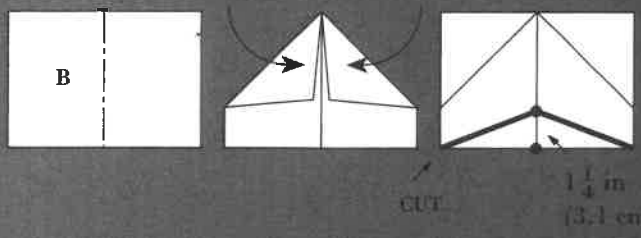
STEP 5 Unfold fuselage completely. Refold applying glue to all contacting surfaces, as shown. Make sure fuselage is straight.



STEP 6 On each side, measure from top (front of fuselage) and mountain fold along broken lines, as shown in enlarged view A. Then flip over fuselage. On each side, valley fold triangle along broken lines, matching fold line to existing crease, as shown in enlarged view B.

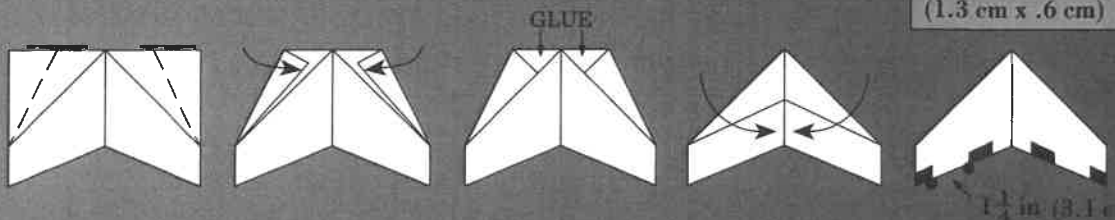


STEP 7 Glue triangles. Hold in place until glue sets. It is important that the fuselage stays straight. Do not glue nose yet.



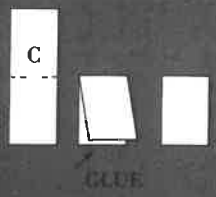
STEP 8 Use piece B to make the wings. Lay paper flat in a horizontal direction. Mountain fold in half vertically. Unfold. Then fold each side diagonally so that upper edges meet center crease. Unfold. Measure and cut trailing (back) edge, as shown by heavy line.

AILERONS	ELEVATORS
$\frac{1}{2}$ in x $\frac{1}{4}$ in	$\frac{3}{4}$ in x $\frac{1}{4}$ in
(1.3 cm x .6 cm)	(1.9 cm x .6 cm)

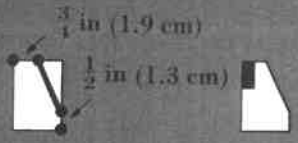


STEP 9 On each side, valley fold diagonally so that outer edge meets previously made diagonal crease. Then apply glue to upper tip only and refold along original diagonal creases.

STEP 10 Flip wings over. On each side, make ailerons and elevators in locations shown.



STEP 11 Use piece C to make the vertical tail. Lay paper flat in a vertical direction. Mountain fold in half horizontally. Glue halves together.



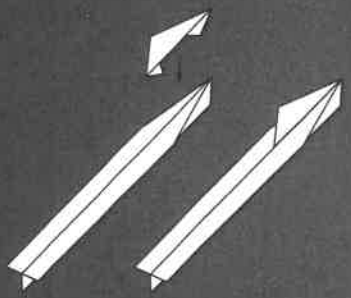
RUDDER
$\frac{3}{4}$ in x $\frac{1}{4}$ in
(1.9 cm x .6 cm)

STEP 12 Measure and cut, as shown. Make rudder in locations shown.

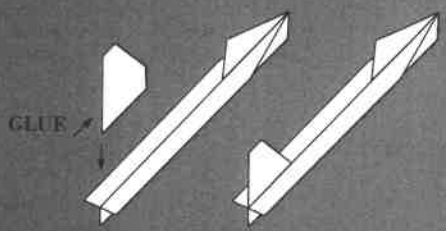
STEP 13 Use piece D to make the fuselage top. Mountain fold in half horizontally. Unfold. Then valley fold so that the outer edges meet center crease. Unfold. At one end, cut slit along center crease, as indicated by heavy line. Shape folds as shown.

CANOPY (type 2)
$1\frac{3}{8}$ in x 3 in (3.5 cm x 7.5 cm)
Top point 2 in (5 cm)

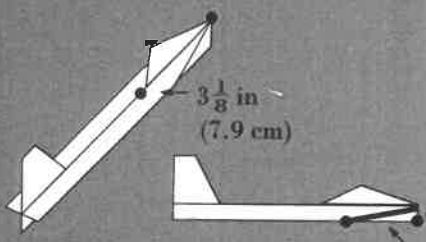
STEP 14 Use piece E to make the canopy. (See p 28).



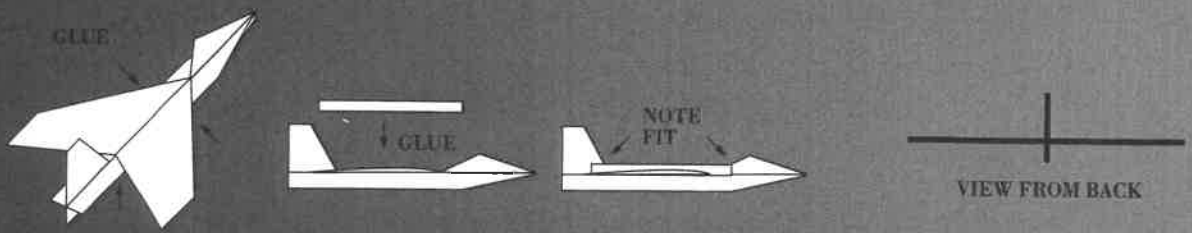
STEP 15 Apply glue to inside of fuselage at the nose end and insert tabs on the bottom of canopy, aligning at the front. Hold until glue sets.



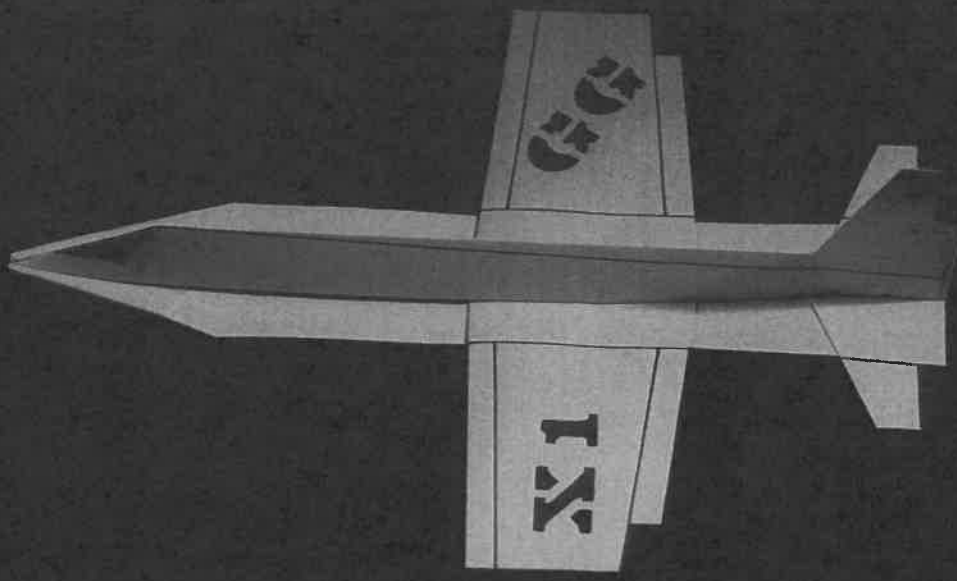
STEP 16 Apply glue to bottom part of vertical tail and insert into back of fuselage, aligning at the back edge.



STEP 17 Measure from front of fuselage and mark where to position wings. Measure and cut nose, as shown by heavy line.



STEP 18 Glue wings to fuselage. Then glue top of fuselage in place so that slit fits around tail and front fits snuggly over back of canopy.



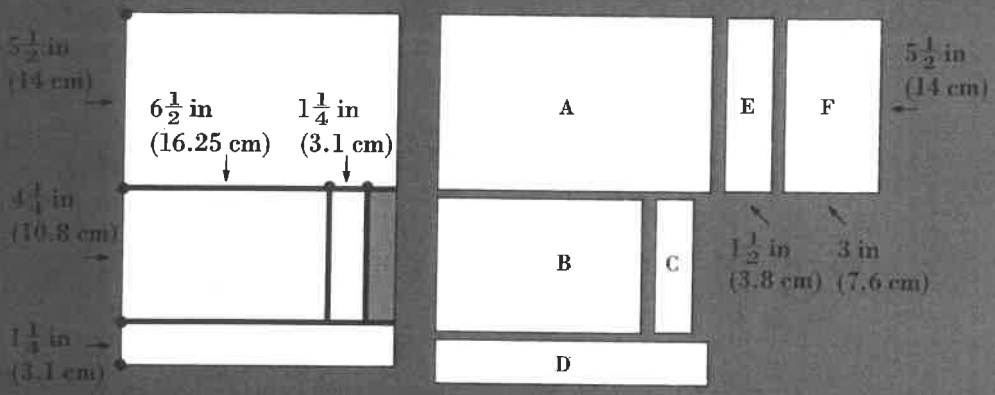
HISTORICAL INFORMATION

Some people believed that the speed of sound was a barrier that would never be crossed. But designers did not abandon their quest. They shaped an airplane like a 50 caliber bullet, which was known to travel faster than the speed of sound. This experimental plane was the stubby-winged Bell X1. It was called "Glamorous Glennis" after the pilot's wife. While this plane did not have swept-back wings, it successfully "broke the sound barrier" for the first time in 1947. Thus began the building of a long series of X planes used for experiments in ultra high speed and high altitude flight. The X15, for example, flew 8 times the speed of sound to the edge of space at an altitude of 70 miles (112 km) in 1956. This paper airplane is modeled on the Bell X1.

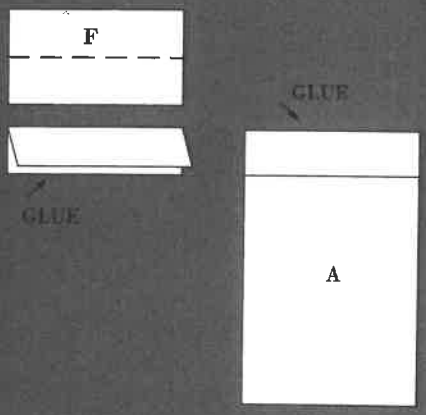
Sound Barrier: What we hear as different sounds are actually differences in air pressure that strike our eardrums. These waves of air (called sound waves) trave at about 760 mph. An airplane traveling at that speed creates a tremendous pressure ridge because so many air molecules are piled up ahead of its leading edges. What makes it so dangerous is that as speed increases, the ridge of pressure moves farther back over the wing and begins to affect the control surfaces which are on the trailing edges. Airplanes that successfully fly faster than the speed of sound must be designed so that the pressure is deflected in such a way that it does not affec aircraft control. Thus, their noses are pointed and thei wings are thin, and either tapered or swept back. The planes must also be built strong enough to withstand th pressure. When supersonic airplanes break the sound barrier they create a loud booming noise (like a clap o thunder), as heard from the ground.

The speed of sound is also called Mach 1, twice that speed Mach 2, three times Mach 3, and so on, in hono of the scientist Ernst Mach.

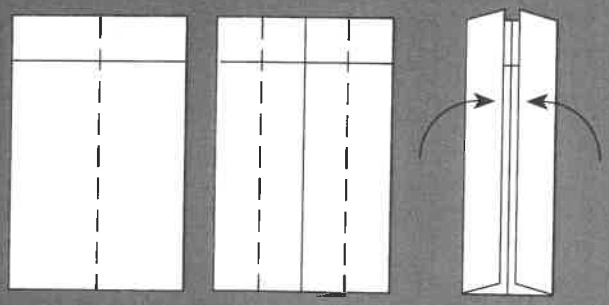
Making the X1



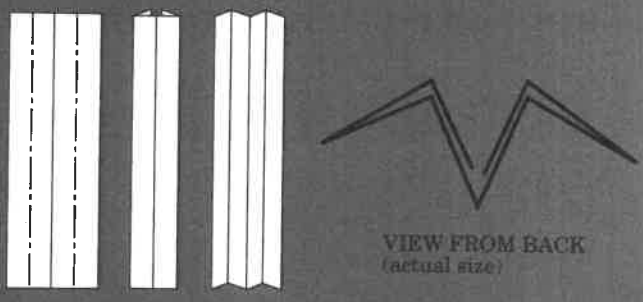
STEP 1 Measure and cut the various pieces from a sheet of bond paper, as shown. Two additional pieces E and F are needed, as shown.



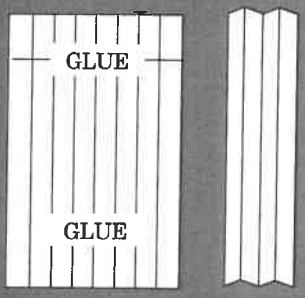
STEP 2 Use piece F to make nose ballast. Lay flat in a horizontal direction and valley fold horizontally. Glue halves together. Then glue to piece A, as shown.



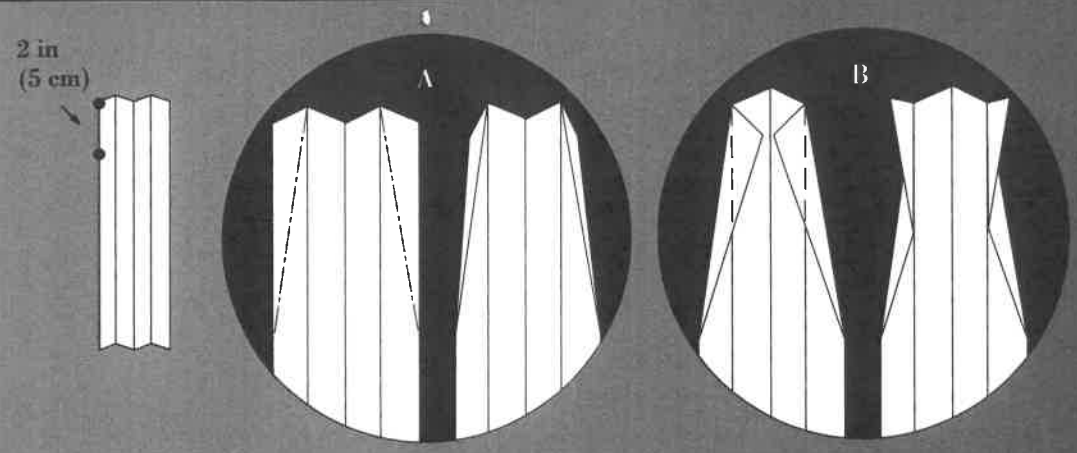
STEP 3 Lay piece A flat in a vertical direction. To make the fuselage, fold in half vertically using a valley fold. Unfold. Then valley fold each side so that outer edges meet center crease, as shown.



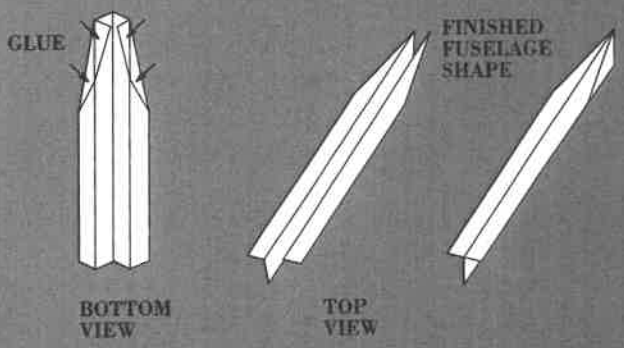
STEP 4 Fold each side again using a mountain fold, so that outer edges meet center crease at back. Then adjust folds so that paper looks like an upside-down W, as shown.



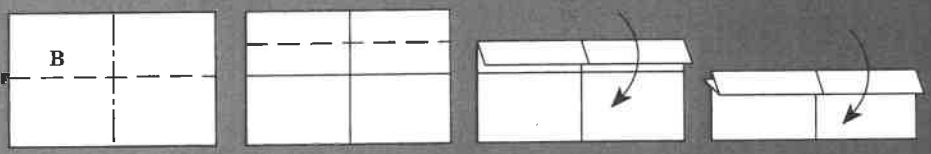
STEP 5 Unfold fuselage completely. Refold applying glue to all contacting surfaces, as shown. Make sure fuselage is straight.



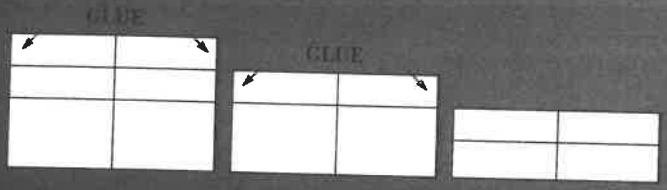
STEP 6 On each side, measure from top (front of fuselage), mark, and mountain fold along broken lines, as shown in enlarged view A. Then flip over fuselage. On each side, valley fold triangle along broken lines, matching fold line to existing crease, as shown in enlarged view B.



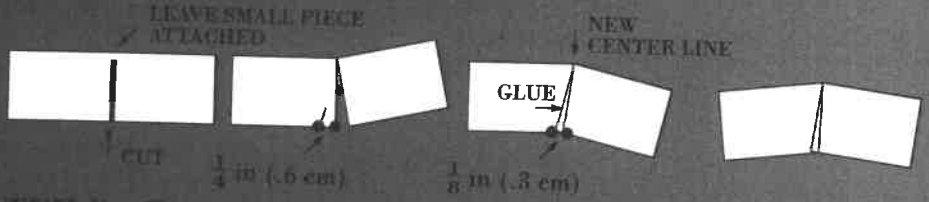
STEP 7 Glue triangles. Hold in place until glue sets. It is important that the fuselage stays straight. Do not glue nose yet.



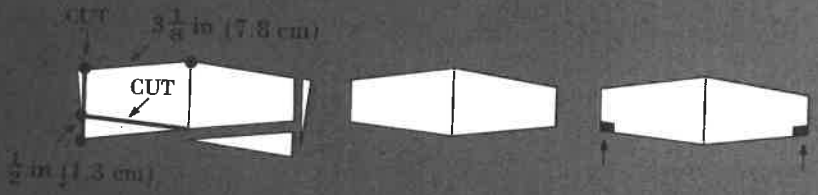
STEP 8 Lay piece B horizontally to make the wings. Fold in half horizontally, using a valley fold. Unfold. Fold in half vertically, using a mountain fold. Unfold. Then valley fold so that upper edge meets center crease. Fold over again along original center crease.



STEP 7 Unfold completely. Refold applying glue to no more than 1 in (2.5) cm) from outer tips, as shown. The folded over part is the bottom of the leading edge (front) of the wings.

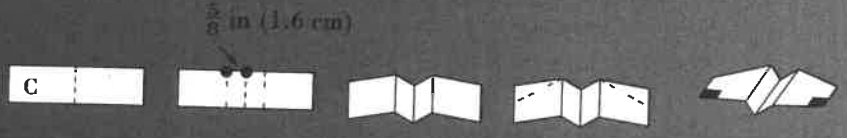


STEP 8 To taper wings, cut along center heavy line from trailing edge (back), leaving a small piece attached at the leading edge. Then measure and make a mark on trailing edge, as shown. Align pieces to the mark. Glue. Measure and draw a new center line.



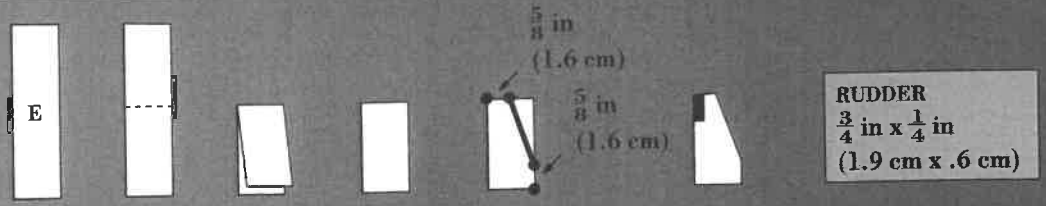
AILERONS
$\frac{1}{2}$ in x $\frac{1}{4}$ in
(1.3 cm x .6 cm)

STEP 9 On each side, measure and cut, as indicated by heavy lines. On the trailing edges of wingtips, make ailerons.

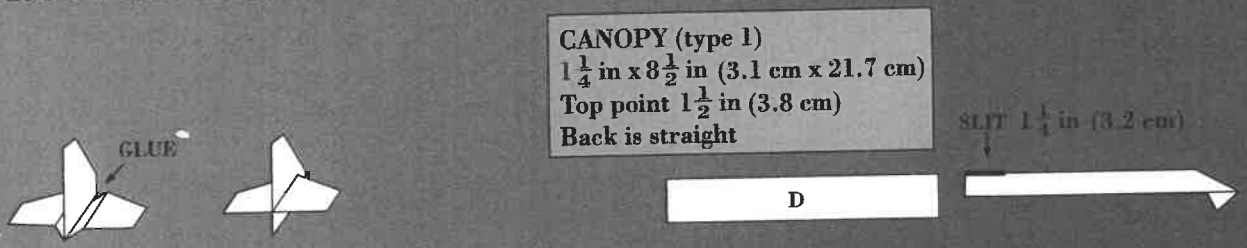


ELEVATORS
$\frac{3}{4}$ in x $\frac{1}{4}$ in
(1.9 cm x .6 cm)

STEP 10 Use piece C to make the horizontal tail. Valley fold in half vertically. Unfold. On each side, measure from center crease, as shown, and mountain fold. On each side, measure and mountain fold leading edge along broken lines. Glue. Make elevators on trailing edges.

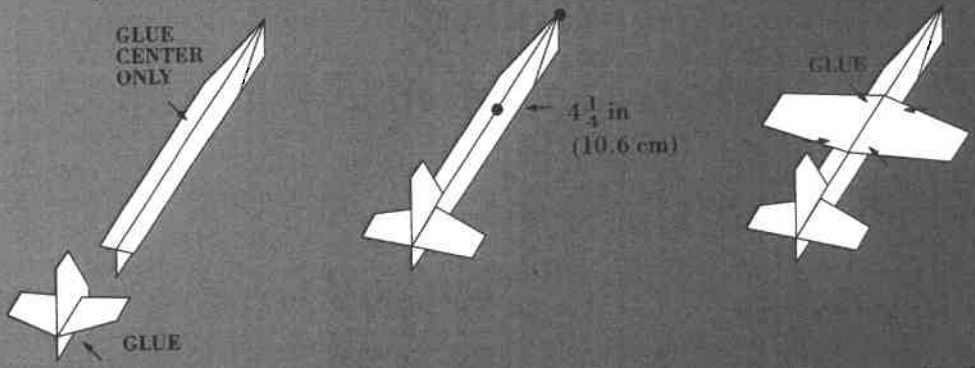


STEP 11 Lay piece E vertically to make the vertical tail. Valley fold in half horizontally and glue halves together. Measure and cut along heavy line, as shown. Make rudder on trailing edge.

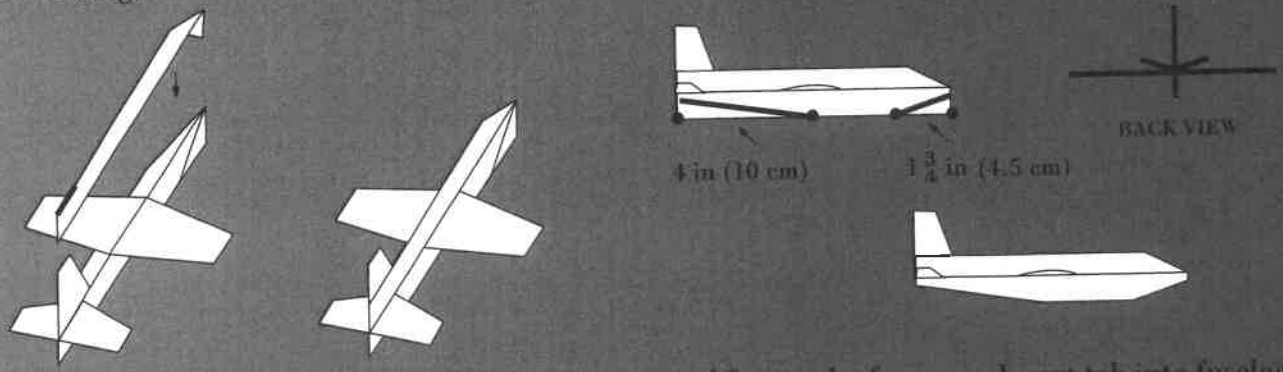


STEP 12 Finish the tail. Apply glue to inside of horizontal tail and slide vertical tail in place, aligning at trailing edge.

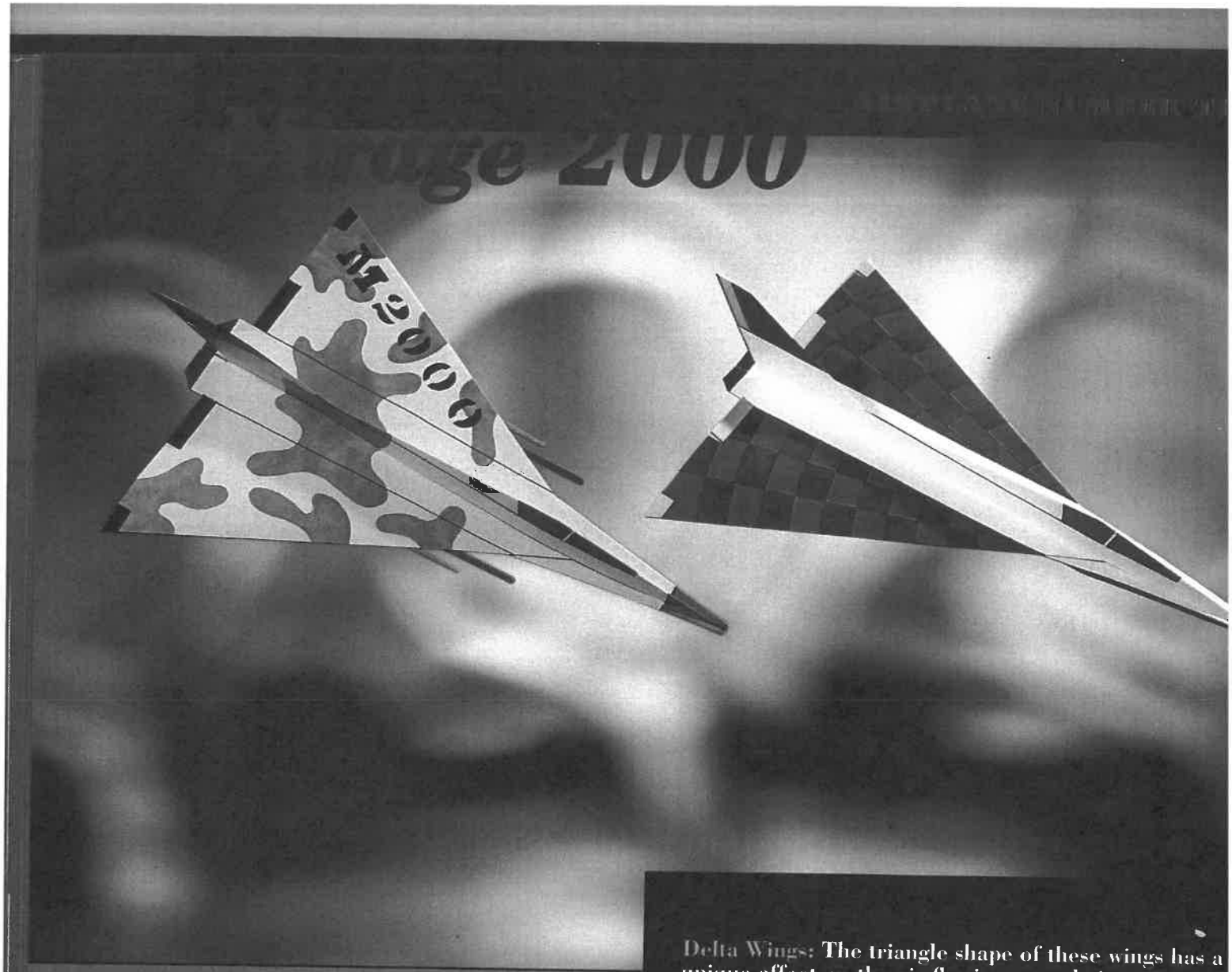
STEP 13 Use piece D to make the canopy (see p 28). Make slit in the back of canopy.



STEP 14 Apply glue to inside center only of fuselage. Then apply glue and slide tail into fuselage, aligning at trailing edge. Measure from front and mark for wing position. Glue wings to fuselage.



STEP 15 Apply glue to inside back of canopy and front tab of canopy. Insert tab into fuselage. The vertical tail fits into slit. Align at nose. To finish, measure and cut front and back of fuselage along heavy diagonal lines, as shown. Adjust dihedral (upward slanting of wings and tail).

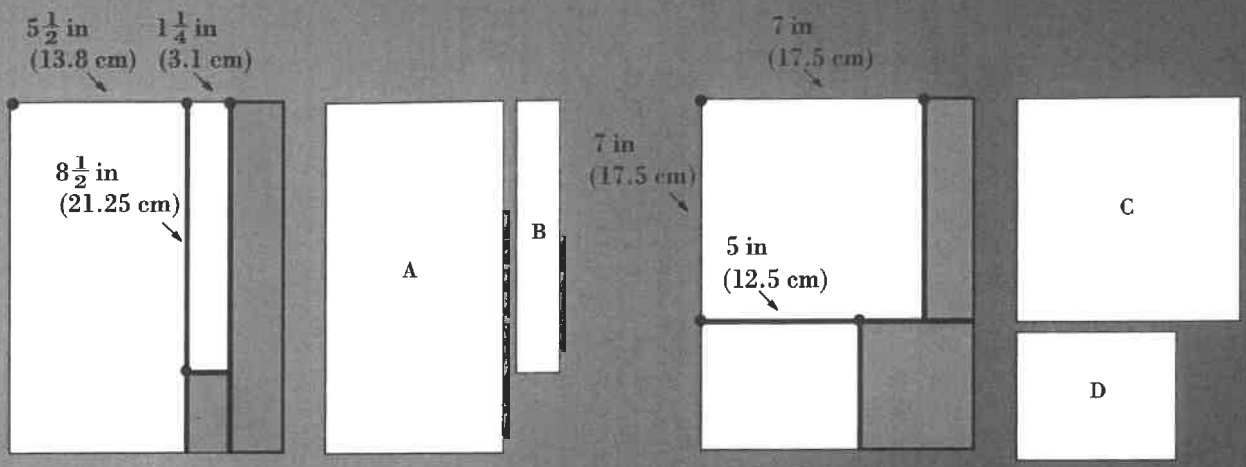


HISTORICAL INFORMATION

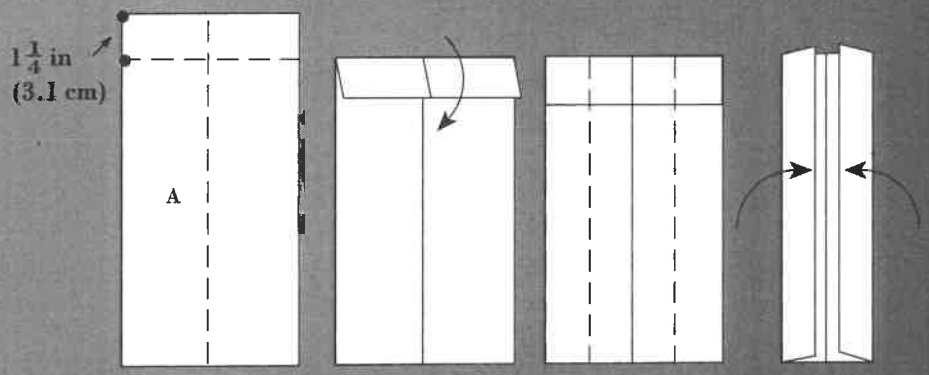
High-speed flight became common after World War II, and wings that swept back came into widespread use because of their efficiency at high speed. Filling in the space between the wingtips of swept-back wings resulted in the formation of triangle shaped wings (delta wings). Delta wings are very stable in flight and are good for supersonic flight. One of their first successful applications was in the early 1950s on the experimental Fairey Delta that exceeded 1000 mph. Two other supersonic planes of the 1950s were the General Dynamics F106 Delta Dart and the Dassault-Breguet Mirage 3. The Mirage has been upgraded several times and is still being built as the Mirage 2000. This paper airplane is modeled on it.

Delta Wings: The triangle shape of these wings has a unique affect on the air flowing over their upper surfaces. The air flows diagonally towards the fuselag Like swept-back wings, delta wings prevent the build of the pressure ridge created by high speed flight. In addition, the shape lends added stability, and most de wing airplanes need no additional horizontal stabilize However, because they are so stable, some fighter plan have surfaces added to make them less stable and mo maneuverable. Delta wings can operate at much great angles of attack before the air flowing over the top surfaces becomes turbulent and the wings stall.

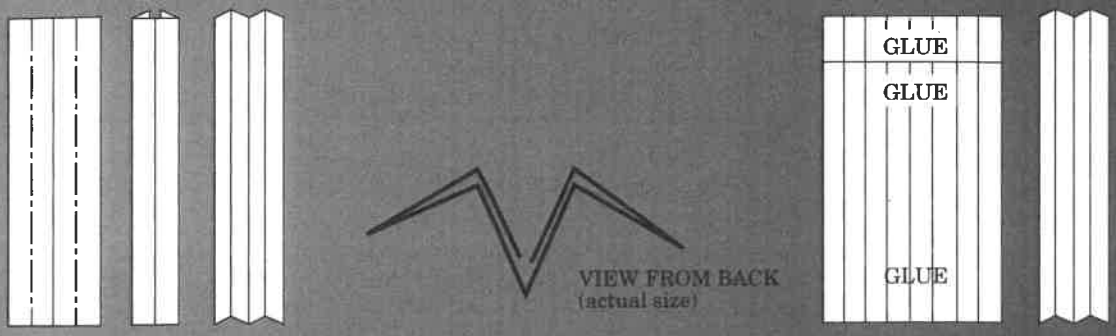
Making the Mirage



STEP 1 Measure and cut the various pieces from two sheets of bond paper.

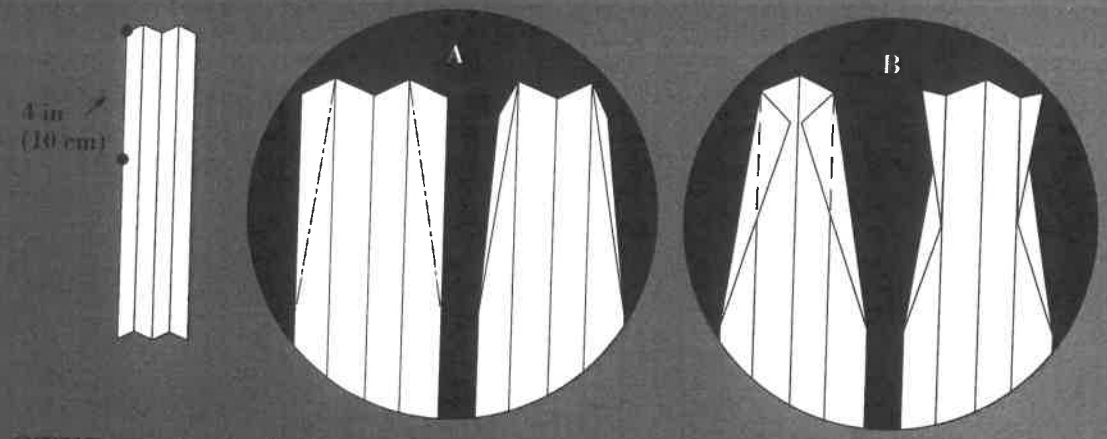


STEP 2 Lay piece A vertically to make the fuselage. Fold in half vertically using a valley fold. Unfold. Measure from top and valley fold, as shown. Valley fold each side so that outer edges meet center crease, as shown.

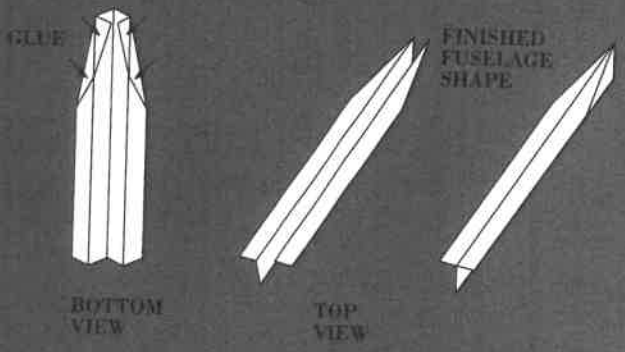


STEP 3 Fold each side again using a mountain fold, so that outer edges meet center crease at back. Then adjust folds so that paper looks like an upside-down W, as shown.

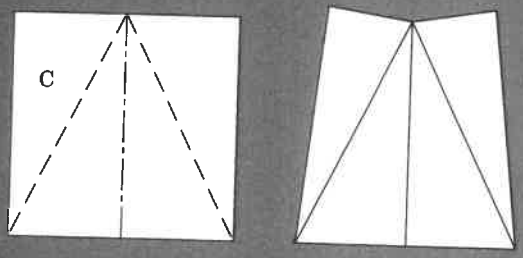
STEP 4 Unfold fuselage completely. Refold, applying glue to contacting surfaces, as shown. Make sure fuselage is straight.



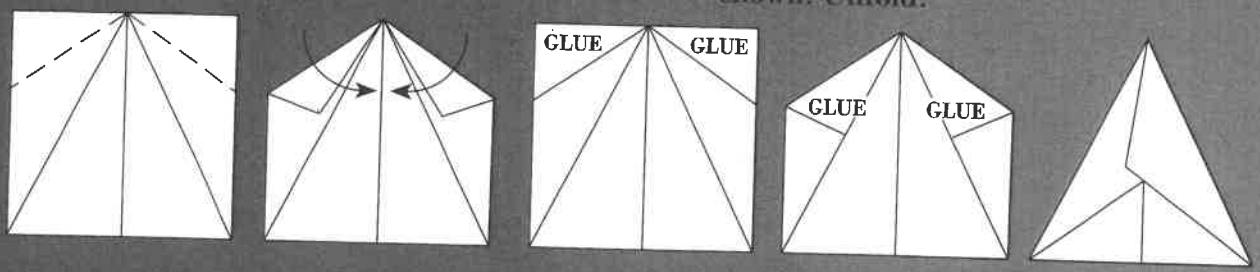
STEP 5 On each side, measure from top (front of fuselage), mark, and mountain fold along broken lines, as shown in enlarged view A. Then flip over fuselage. On each side, valley fold triangle along broken lines, matching fold line to existing crease, as shown in enlarged view B.



STEP 6 Glue triangles. Hold in place until glue sets. It is important that the fuselage stays straight. Do not glue nose yet.

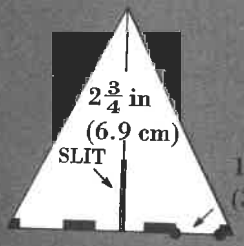


STEP 7 Use piece C to make the wings. Mountain fold in half vertically. Unfold. Draw a line from the top center to the lower corners and valley fold along lines, as shown. Unfold.



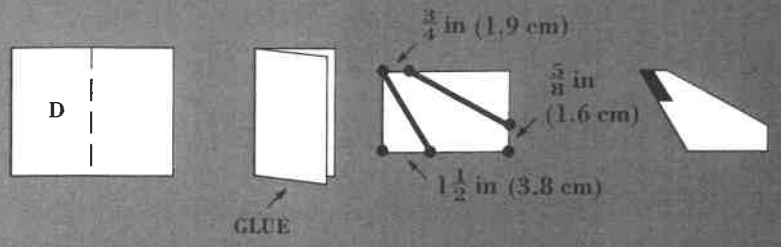
STEP 8 On each side, valley fold so that top edge meets the diagonal crease.

STEP 9 Unfold completely. Refold, applying glue to both sides of small upper triangles only. Flip over and finish wings. Add ailerons and elevators, in locations shown. Make slit, as shown by heavy line.



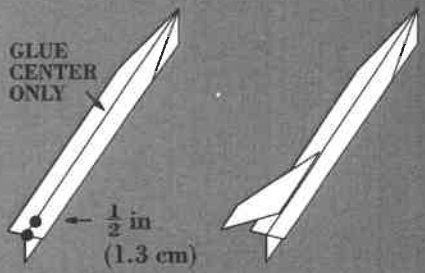
AILERONS
$\frac{1}{2}$ in x $\frac{1}{4}$ in
(1.3 cm x .6 cm)

ELEVATORS
1 in x $\frac{1}{4}$ in
(2.5 cm x .6 cm)

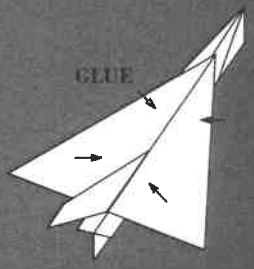


RUDDER
1 in x ¼ in
(2.5 cm x .6 cm)

STEP 10 Lay piece D horizontally to make the vertical tail. Valley fold in half vertically. Glue halves together. Turn, as shown, measure, mark, and cut along heavy lines. Make rudder on trailing edge, as shown.

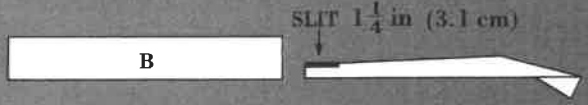


STEP 11 Apply glue to inside center only of fuselage. Measure from back of fuselage and mark, as shown. Then apply glue and slide tail into fuselage, aligning at mark.

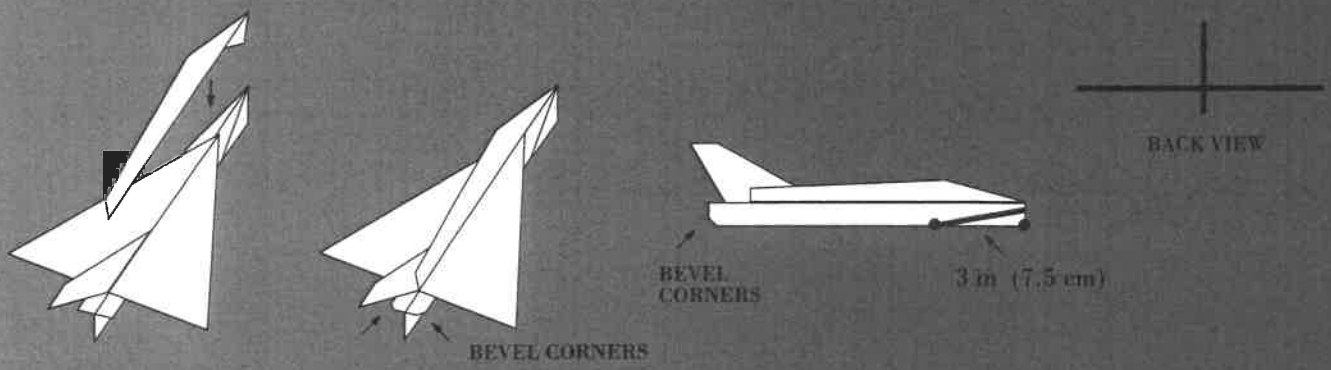


STEP 12 Apply glue and attach wings to fuselage, slipping around vertical tail. Align trailing edge at the mark.

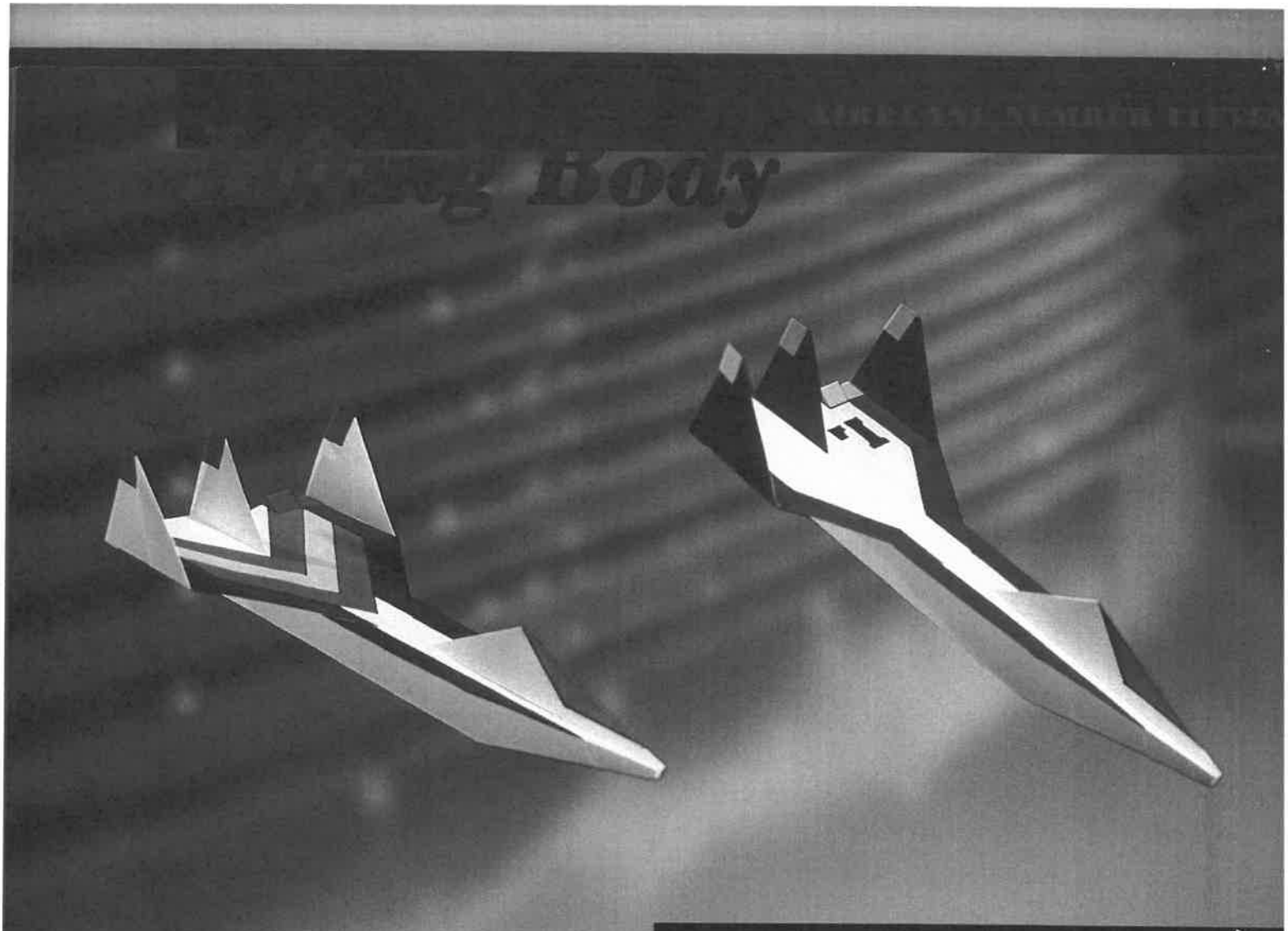
CANOPY (type 1)
1¼ in x 8½ in (3.1 cm x 21.7 cm)
Top point 3 in (7.5 cm)
Back ⅜ in (1 cm)



STEP 13 Use piece B to make canopy (see p 28). Make a slit at center back of canopy.



STEP 14 Apply glue to inside back of canopy and front tab of canopy. Insert tab into fuselage. The vertical tail fits into slit. Align at nose. Measure and cut front of fuselage along heavy diagonal line, as shown. To finish, bevel all corners on fuselage back, as shown.

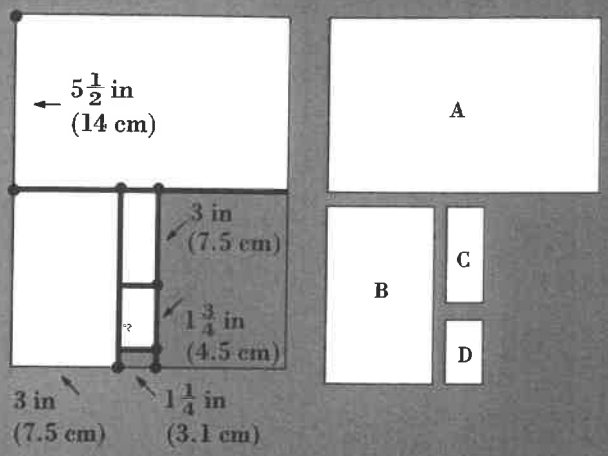


HISTORICAL INFORMATION

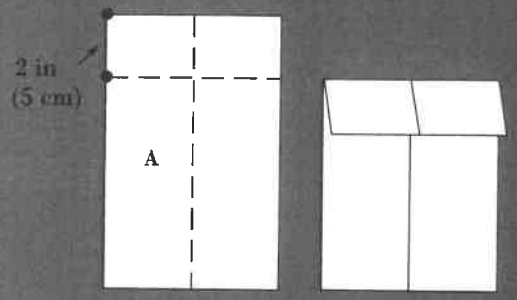
In the 1960s experiments were conducted into designing airplanes with flattened and widened fuselages so that these became lift-producing. This allowed for much smaller wings. Among these planes was the American built X20 Dyna-Soar. Others were the Soviet built Cosmos series of planes, that were actually rocketed into space. All the lifting-body research planes were used to study high speed gliding (therefore the word "soar" in the X20 name). The information gathered was used primarily in developing space vehicles. This paper airplane is modeled on the lifting-body research planes.

Lifting Bodies: The lifting-body research airplanes were not intended for operational use. They were used to demonstrate that wedge-shaped airplanes with very stubby wings could actually fly. Having small wings is important in an airplane that is to be rocketed into space orbit at high speed. Large wings could not stand the stress and would rip off. The angle of attack is very important in the flight of these planes, and is greater than in most airplanes. Because their wings are so small, these planes are roll-unstable. Some experimental planes rocked back and forth wildly in flight. This problem was eventually solved. One successful application of lifting-body research is the Space Shuttle. On its return from space orbit, the shuttle is the world's heaviest and fastest glider.

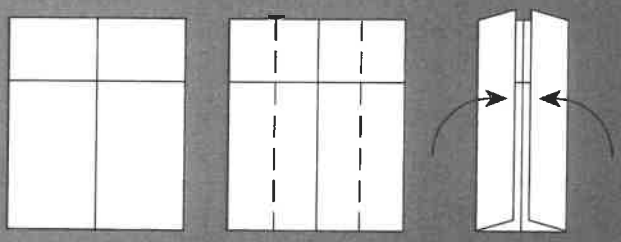
Making the Lifting Body



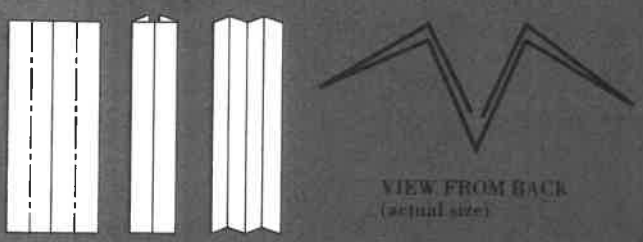
STEP 1 Measure and cut the various pieces from a sheet of bond paper, as shown.



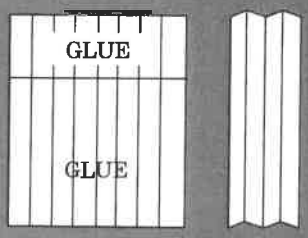
STEP 2 Lay piece A flat in a vertical direction. To make the fuselage, fold in half vertically using a valley fold. Unfold. Measure from top and valley fold, as shown.



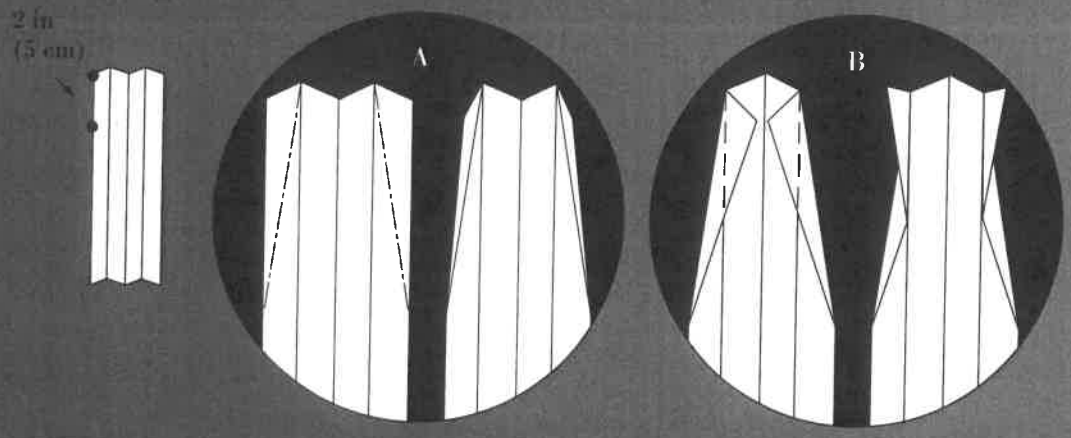
STEP 3 Valley fold each side so that outer edges meet center crease, as shown.



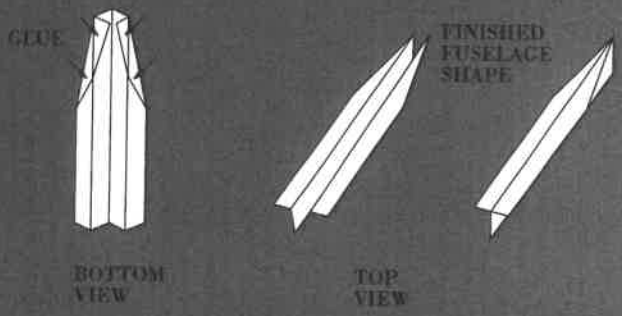
STEP 4 Fold each side again using a mountain fold, so that outer edges meet center crease at back. Then adjust folds so that paper looks like an upside-down W, as shown.



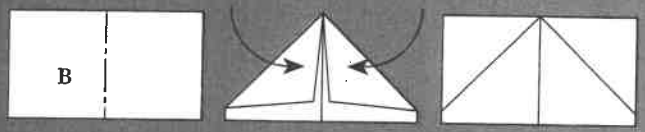
STEP 5 Unfold fuselage completely. Refold applying glue to all contacting surfaces, as shown. Make sure fuselage is straight.



STEP 6 On each side, measure from top (front of fuselage), mark, and mountain fold along broken lines, as shown in enlarged view A. Then flip over fuselage. On each side, valley fold triangle along broken lines, matching fold line to existing crease, as shown in enlarged view B.

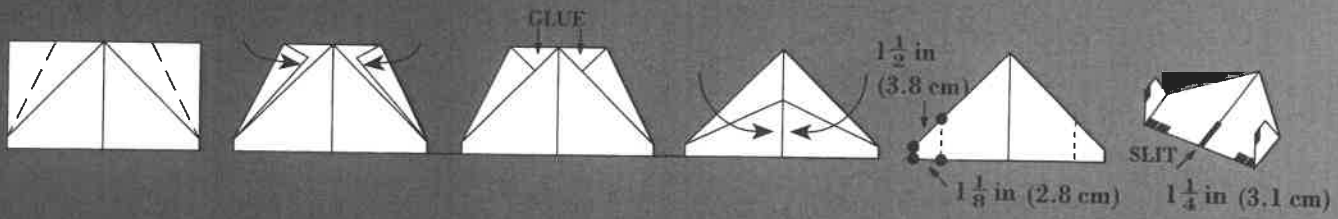


STEP 7 Glue triangles. Hold in place until glue sets. It is important that the fuselage stays straight. Do not glue nose yet.



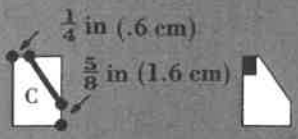
STEP 8 Use piece B to make the wings. Lay paper flat in a horizontal direction. Mountain fold in half vertically. Unfold. Then fold each side diagonally so that upper edges meet center crease. Unfold.

RUDDERS	AILERONS	ELEVATORS
$\frac{3}{8}$ in x $\frac{1}{4}$ in (1 cm x .6 cm)	$\frac{3}{8}$ in x $\frac{1}{4}$ in (1 cm x .6 cm)	$\frac{3}{8}$ in x $\frac{1}{4}$ in (1 cm x .6 cm)



STEP 9 On each side, valley fold diagonally so that outer edge meets previously made diagonal crease. Then apply glue to upper tip only and refold along original diagonal creases. Flip wings over. On each side, measure and valley fold wingtips to make vertical tails.

STEP 10 Make a slit at the center back of wings, as shown. Make rudders, ailerons, and elevators in locations shown.

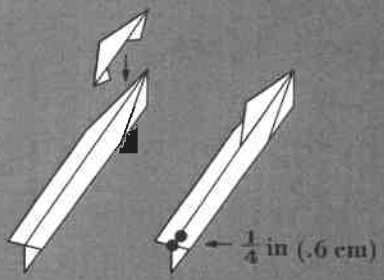


RUDDER
$\frac{3}{8}$ in x $\frac{1}{4}$ in
(1 cm x .6 cm)

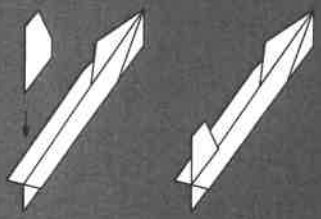
STEP 11 Use piece C to make a center vertical tail. Measure and cut, as shown. Make rudder in location shown.

CANOPY (type 2)
$1\frac{1}{4}$ in x 3 in (3.1 cm x 7.5 cm)
Top point 2 in (5 cm)

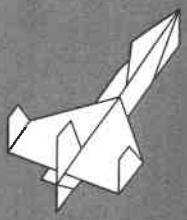
STEP 12 Use piece D to make the canopy. (See p 28).

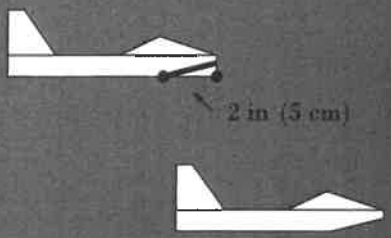


STEP 13 Applying glue to inside of fuselage at the nose end, insert tabs on the bottom of canopy, aligning at front. Measure from back of fuselage and mark wing position.



STEP 14 Applying glue to bottom part of vertical tail, insert into back of fuselage, aligning at back edge.

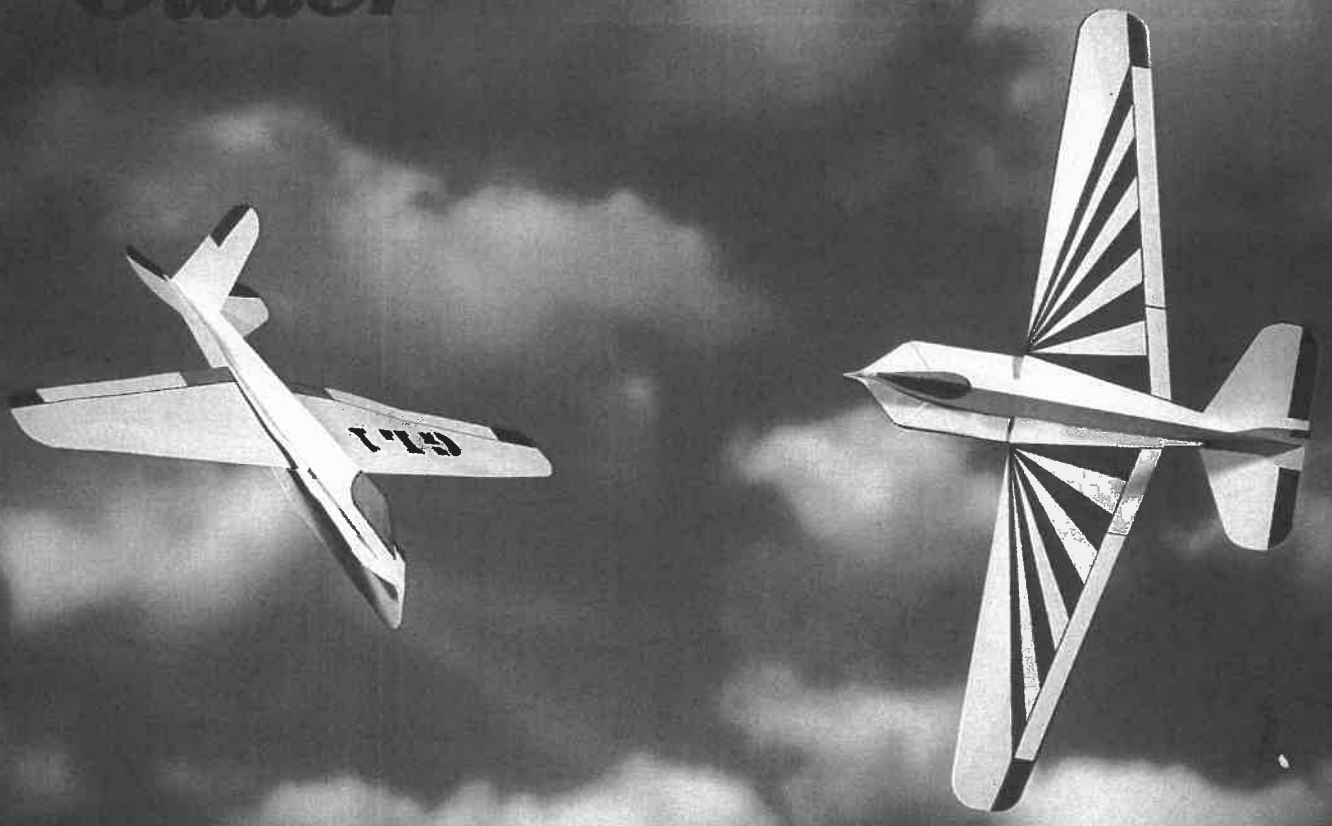




STEP 15 Glue wings to fuselage. Align trailing (back) edge to the mark so that slit fits around center vertical tail.

STEP 16 Measure from front of fuselage and cut nose, as shown by heavy diagonal line. Adjust vertical tails to be vertical.

Glider

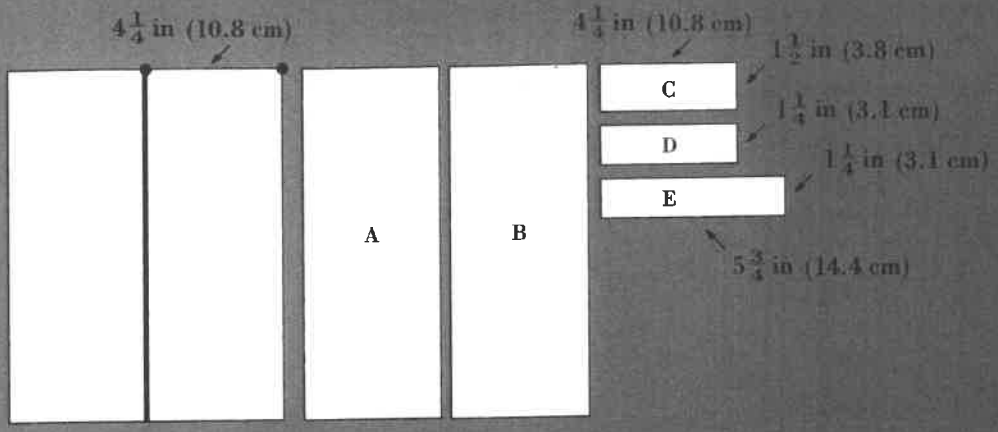


HISTORICAL INFORMATION

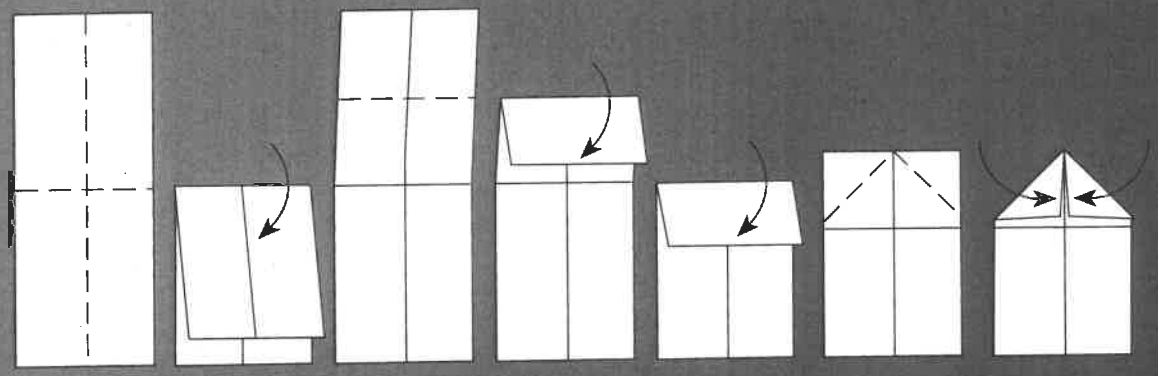
While Wilber Wright was mainly interested in powered flight, his brother Orville experimented with gliders. Both types of flight continued to be developed. By the time World War II ended much had been learned about good aerodynamic performance. During the 1950s and 60s the design of gliders was greatly improved as builders produced low-drag gliders with highly efficient wings. With long soaring flights now possible, Orville's dream of sustained motorless flight was fulfilled. In Europe, Germany became well known for its gliders. In the USA, the Schweizer brothers of New York built good training gliders that did much to promote gliding in North America. Soaring became a popular sport the world over. This paper airplane is modeled on gliders.

Aspect Ratio: Wings that are short, like the ones fou on the X1 and the Lifting Body, have a low aspect ra Wings that are long and slender have a high aspect ra Wings with a high aspect ratio produce more lift for amount of drag they create. This makes them suitabl for gliders, where the smallest amount of drag possil is best. Today's gliders are very efficient. They soar the eagles. From an altitude of 6000 ft (1800 m) so of them can fly about 60 nautical miles forward with any additional lift. To gain altitude, pilots usually tak advantage of columns of rising air. (This is air that h been warmed by the ground on a sunny day, making lighter and consequently making it rise.) Some glider pilots have remained airborne for more than ten hou and flown distances of more than 1000 nautical mile without landing. They have reached altitudes of mor than 40,000 ft (12,000 m). Because the columns of rising air are invisible, it takes skill, and sometimes lu to find and stay in them. Many countries have nationa gliding competitions where the best pilots demonstrat their skills.

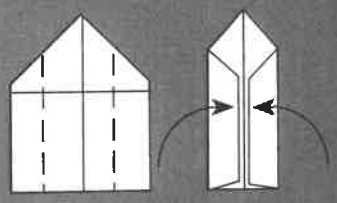
Making the Glider



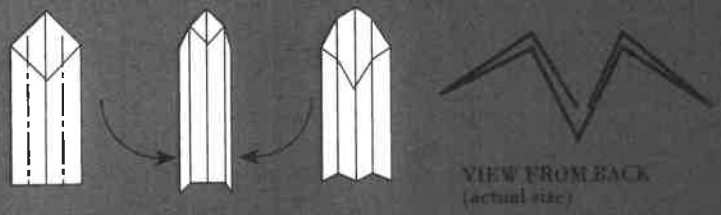
STEP 1 Measure and cut a sheet of bond paper, as shown. Three additional pieces are needed, as shown.



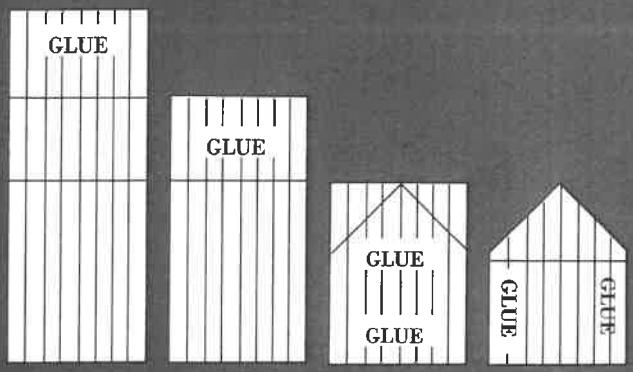
STEP 2 To make the fuselage, fold piece A in half vertically using a valley fold. Unfold. Valley fold in half horizontally. Unfold. Then valley fold so that upper edge meets horizontal crease. Refold original horizontal crease. Then on each side, valley fold diagonally so that top edge meets center crease.



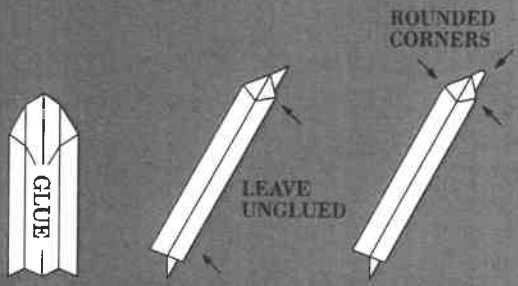
STEP 3 Valley fold each side so that outer edges meet center crease, as shown.



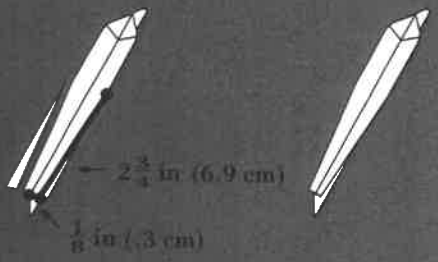
STEP 4 Fold again using a mountain fold, so that outer edges meet center crease at back. Then adjust folds so that paper looks like an upside-down W, as shown.



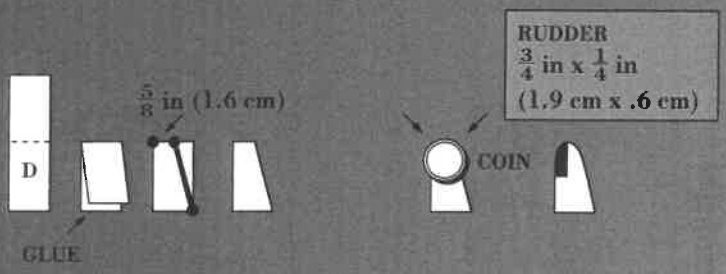
STEP 5 Unfold fuselage completely. Refold, applying glue to contacting surfaces, as shown. Make sure fuselage is straight.



STEP 6 Glue center of fuselage, leaving 1 in (2.5 cm) at the nose and 1 in (2.5 cm) at the tail end unglued. Round corners at nose end.



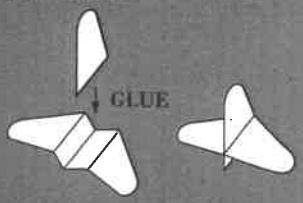
STEP 7 On each side, measure and cut fuselage back, as shown by heavy lines.



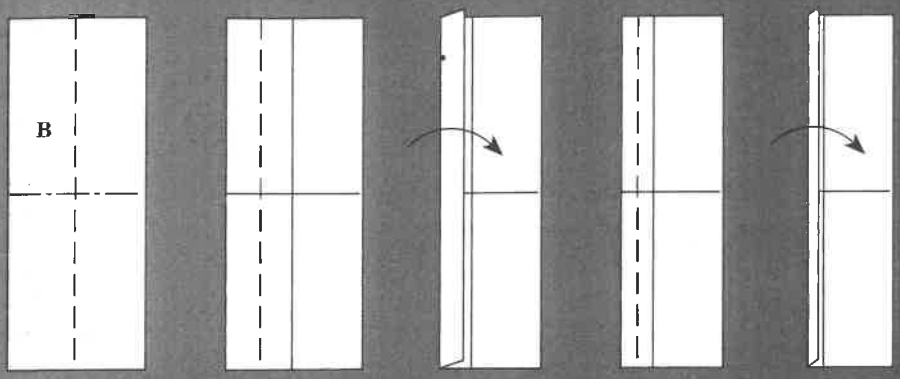
STEP 8 Lay piece D vertically to make the vertical tail. Valley fold in half horizontally. Glue halves together. Measure and cut leading edge along heavy line, as shown. Trace around a coin and cut out to round corners (see p 26). On trailing edge, make rudder.

STEP 9 Use piece C to make the horizontal tail. Valley fold in half vertically. Unfold. On each side, measure from center crease, as shown, and mountain fold. On each side, measure and cut leading edges along heavy lines, as shown.

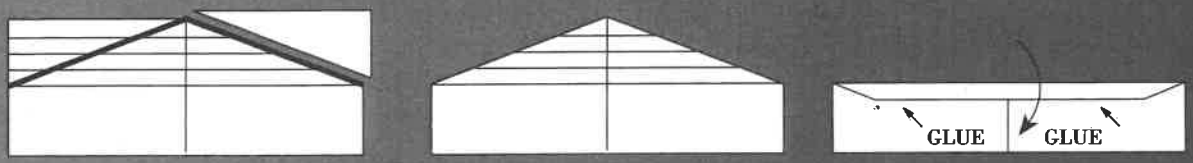
STEP 10 Trace around a coin and cut out to make all the corners rounded (see p 26). On trailing edges, make elevators.



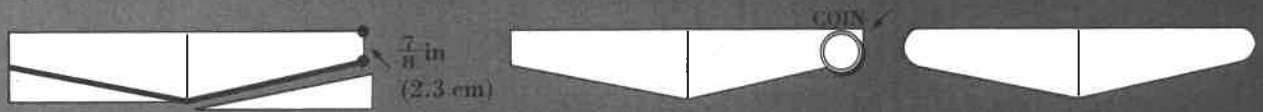
STEP 11 Apply glue to inside of horizontal tail and insert vertical tail, aligning trailing edges.



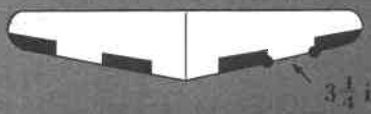
STEP 12 Use piece B to make the wings. Fold in half horizontally, using a mountain fold. Unfold. Fold in half vertically, using a valley fold. Unfold. Then valley fold so that outer edge meets center crease. Fold same side again so that outer edge again meets center crease. Refold original horizontal center crease.



STEP 13 Unfold completely. On each side, draw and cut diagonally along heavy lines, as shown. Refold. Apply glue before refolding original horizontal center crease only. The folded over part is the bottom of the leading edge (front) of the wings. These slender wings are quite fragile. When they are completed, make sure they are not twisted.

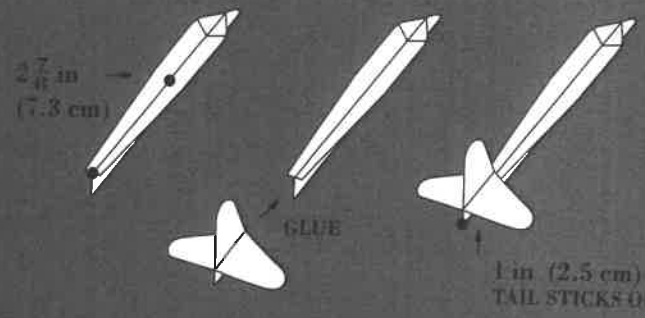


STEP 14 Measure and cut trailing edge (back) of wings, as shown by heavy lines. Then trace around a coin and cut out to make rounded corners at both leading edges and trailing edges, as shown (see p 26).

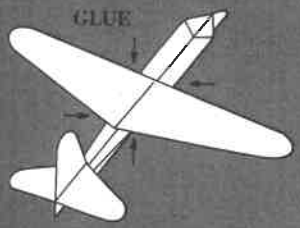


AILERONS	FLAPS
$\frac{3}{4}$ in x $\frac{1}{4}$ in	$1\frac{1}{4}$ in x $\frac{1}{4}$ in
(1.9 cm x .6 cm)	(3.1 cm x .6 cm)

STEP 15 At wingtips on trailing edges, make ailerons. Then make secondary control surfaces (flaps), in locations shown.

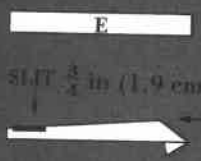


STEP 16 Measure from back of fuselage and mark position of leading edge (front) of wing. Apply glue and slide tail into back of fuselage.

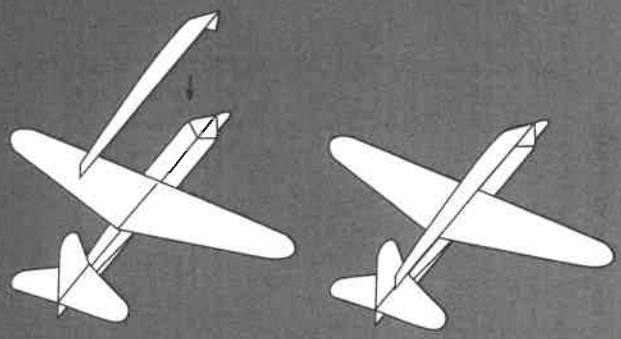


STEP 17 At the mark, attach wings to fuselage.

CANOPY (type 1)
1 1/4 in x 5 3/4 in (3.1 cm x 14.6 cm)
Top point 1 in (2.5 cm)
Back 1/4 in (.6 cm)



STEP 18 Make the canopy, using piece E (see p 28). Make a slit at the center back, as shown. Round the top point slightly.



STEP 19 Apply glue to inside back and front tab of canopy. Insert tab into fuselage, sliding vertical tail into slit. Align at nose.

STEP 20 Measure and cut back of fuselage along heavy diagonal line, as shown. Adjust dihedral (upward slanting of wings and tail), as shown.

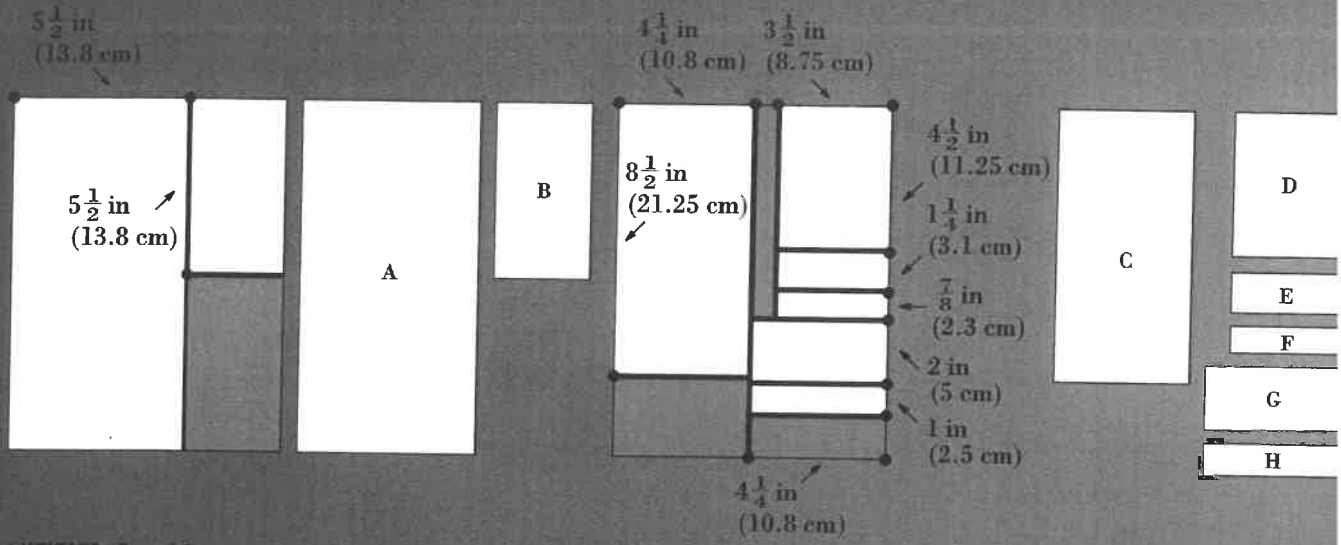
F16 Falcon

HISTORICAL INFORMATION

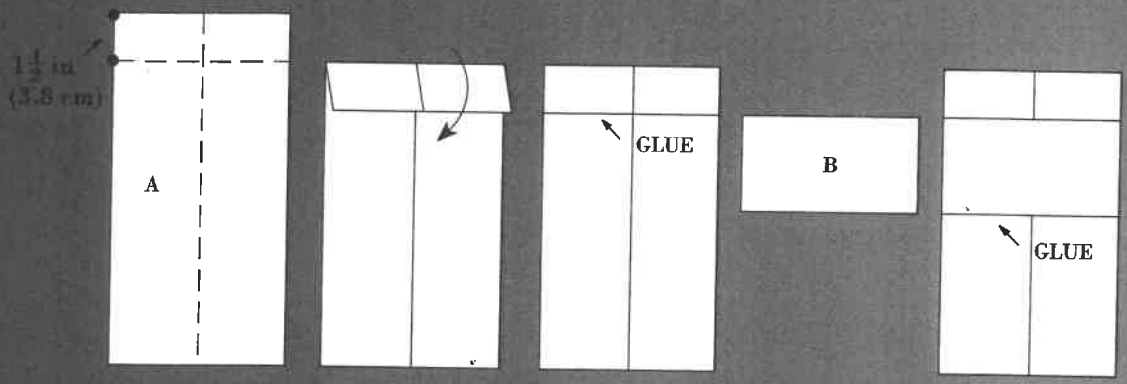
In the early 1970s the General Dynamics F16 was an experimental airplane used to test new lightweight materials and computer technology. Since then it has become one of the most maneuverable and versatile fighter planes ever made, and is used for a wide range of military tasks. It can be found in the air forces of at least ten countries. Its ailerons, elevators, and rudder, as well as navigation and weapons systems, are controlled by computer. The plane has modified delta wings with a conventional tail. For added stability it has a pair of canted (slanted) ventral fins beneath the horizontal stabilizers. It is commonly called the "Falcon". This paper airplane in modeled on the F16.

The F16 has a flattened fuselage, something like a liftin body. While the wings of this plane are basically triangular, they attach to the fuselage with extensions on the leading edges called strakes. They improve the flight characteristics of the plane at very low and very high speeds. In this paper model the flattened fuselage acts as part of the leading edge extensions. The F16 has a single turbojet engine with an afterburner and ca fly twice the speed of sound at an altitude of 60,000 f (18,000 m). Its air intake is situated in line with the canopy underneath the fuselage. The F16 has much improved fuel efficiency over older jet fighters. It has a missile rail at each wingtip, and can carry extra fuel tanks as well as a variety of armament under the wings This makes it useful for both air-to-air and air-to-groun military operations. Besides its military role, this aircraf is also used as an aerial display plane at air shows.

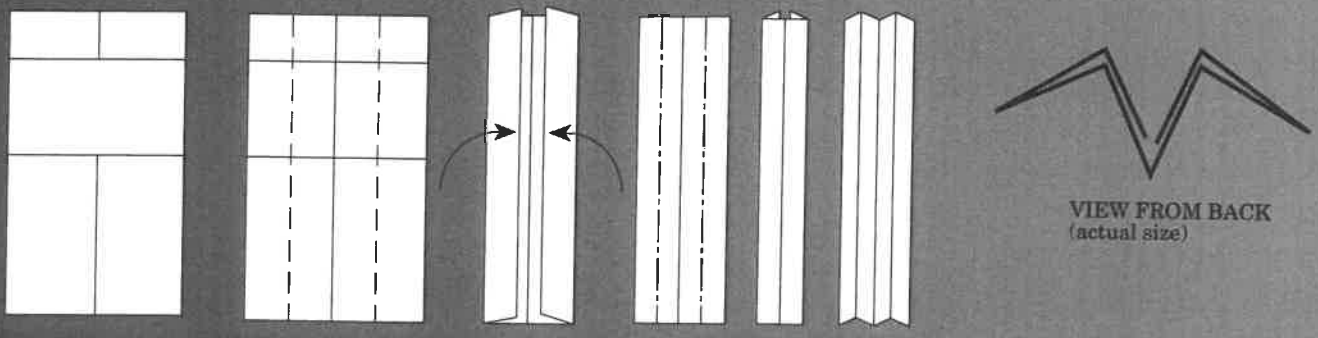
Making the F16



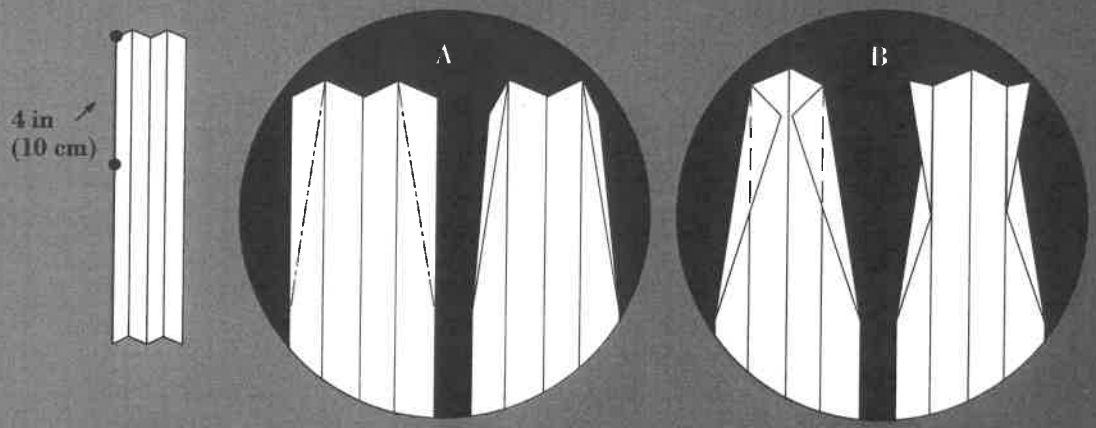
STEP 1 Measure and cut the various pieces from two sheets of bond paper, as shown.



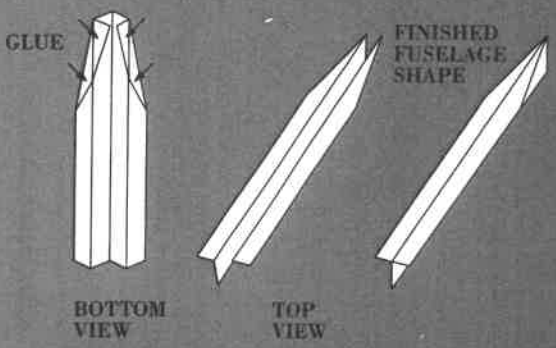
STEP 2 Lay piece A flat in a vertical direction. To make the fuselage, fold in half vertically using a valley fold. Unfold. Measure and valley fold horizontally, as shown. Glue this flap down. Then glue piece B in place, aligning against the glued-down flap, as shown.



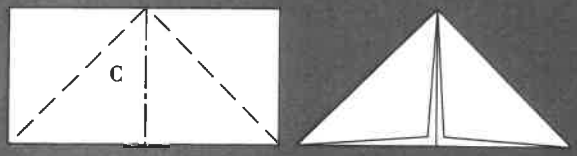
STEP 3 Refold in half vertically using a valley fold. Unfold. Valley fold each side so that the outer edges meet center crease, as shown. Fold each side again using a mountain fold, so that outer edges meet center crease at back. Then adjust folds so that paper looks like an upside-down W, as shown.



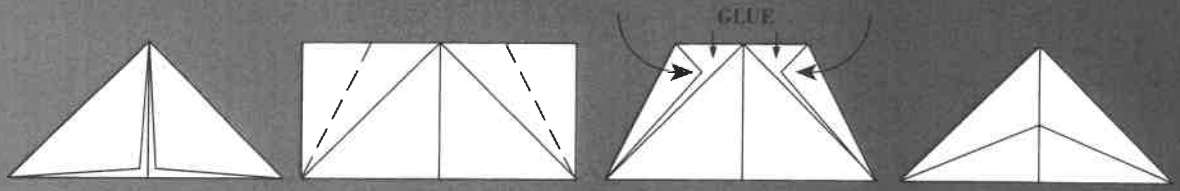
STEP 4 On each side, measure from top (front of fuselage), mark, and mountain fold along broken lines, as shown in enlarged view A. Then flip over fuselage. On each side, valley fold triangle along broken lines, matching fold line to existing crease, as shown in enlarged view B.



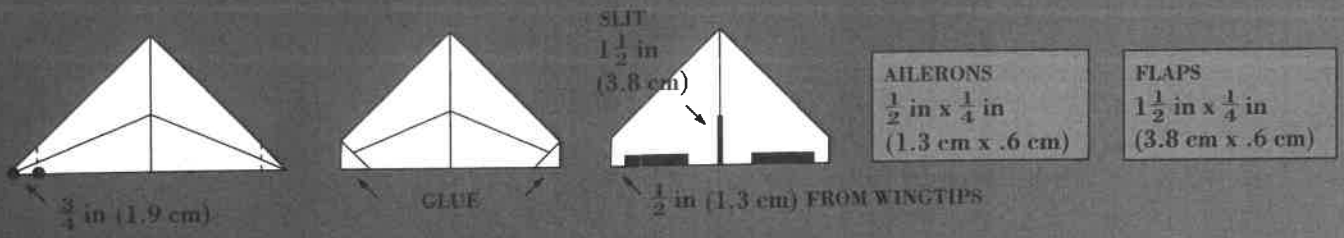
STEP 5 Glue triangles. Hold in place until glue sets. It is important that the fuselage stays straight. Do not glue nose yet.



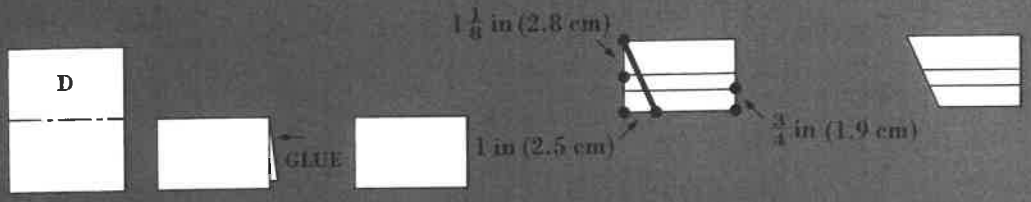
STEP 6 Use piece C to make the wings. Fold in half vertically, using a mountain fold. Unfold. On each side, valley fold diagonally so that top edge meets center crease, as shown.



STEP 7 Unfold diagonal folds. On each side, valley fold diagonally so that outer edges meet diagonal crease, as shown. Apply glue to small upper triangles only and refold original diagonal creases.



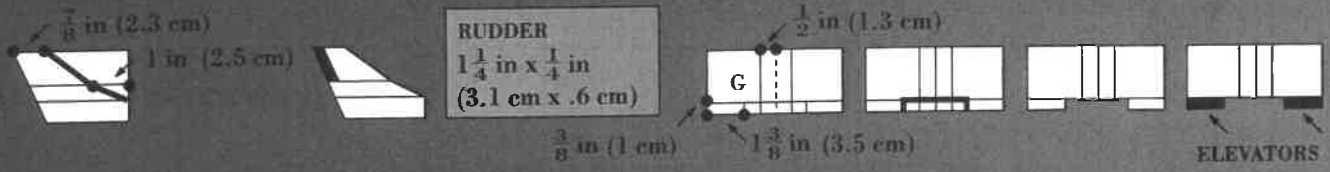
STEP 8 At each wingtip, measure and valley fold, as shown. Glue down the small triangles. Flip over and make ailerons and flaps in locations shown. At the trailing edge, make a slit along the center crease.



STEP 9 Mountain fold piece D in half horizontally to make the vertical tail. Glue halves together.

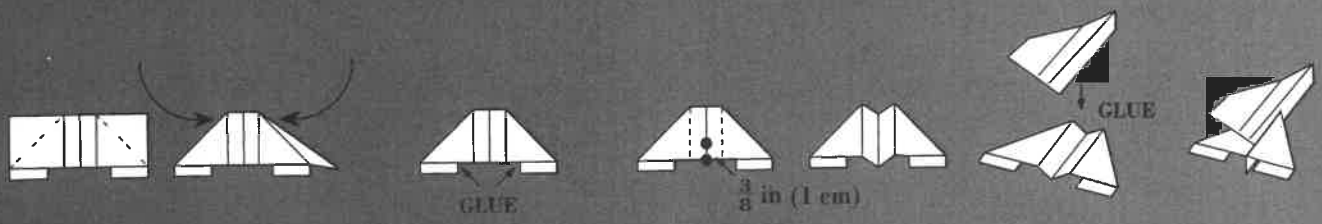
STEP 10 Measure and draw lines, as shown. Cut diagonally, as shown by heavy lines.

ELEVATORS
$1\frac{3}{8}$ in x $\frac{3}{8}$ in
(3.5 cm x 1 cm)



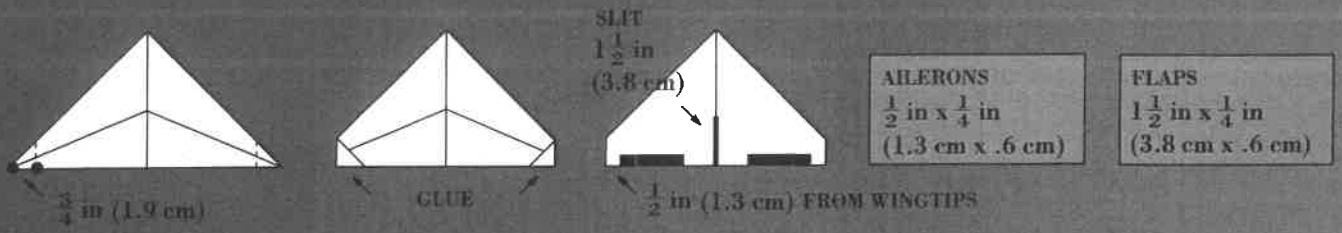
STEP 11 Measure and draw additional lines to make leading edge, as shown. Cut diagonally, as shown by heavy lines. Add rudder.

STEP 12 Use piece G to make horizontal tail. Valley fold in half vertically. Unfold. On each side, measure and draw lines. To make elevators, cut out piece, as shown by heavy lines.

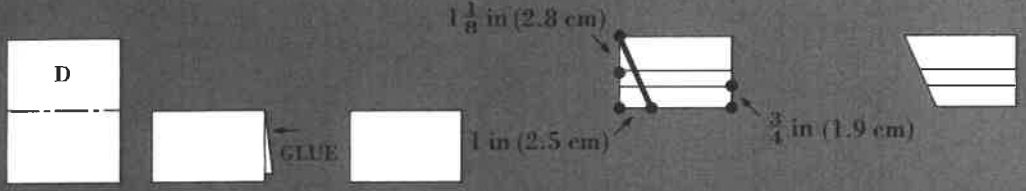


STEP 13 On each side, mountain fold diagonally so that upper edge meets vertical crease, as shown. Glue.

STEP 14 Measure from back and make a mark. On each side, mountain fold along lines, as shown. Apply glue to inside of horizontal tail and isert vertical tail, aligning trailing edge (back) to the mark.

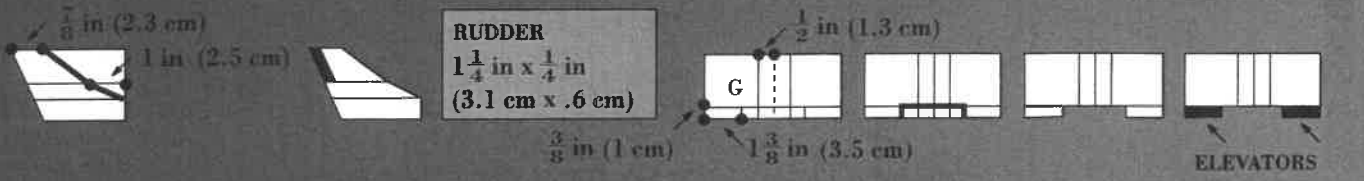


STEP 8 At each wingtip, measure and valley fold, as shown. Glue down the small triangles. Flip over and make ailerons and flaps in locations shown. At the trailing edge, make a slit along the center crease.



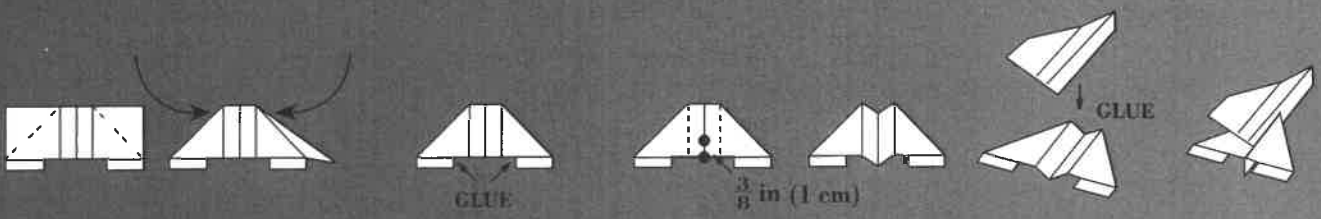
STEP 9 Mountain fold piece D in half horizontally to make the vertical tail. Glue halves together.

STEP 10 Measure and draw lines, as shown. Cut diagonally, as shown by heavy lines.



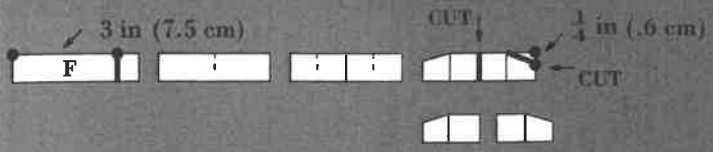
STEP 11 Measure and draw additional lines to make leading edge, as shown. Cut diagonally, as shown by heavy lines. Add rudder.

STEP 12 Use piece G to make horizontal tail. Valley fold in half vertically. Unfold. On each side, measure and draw lines. To make elevators, cut out piece, as shown by heavy lines.



STEP 13 On each side, mountain fold diagonally so that upper edge meets vertical crease, as shown. Glue.

STEP 14 Measure from back and make a mark. On each side, mountain fold along lines, as shown. Apply glue to inside of horizontal tail and isert vertical tail, aligning trailing edge (back) to the mark.

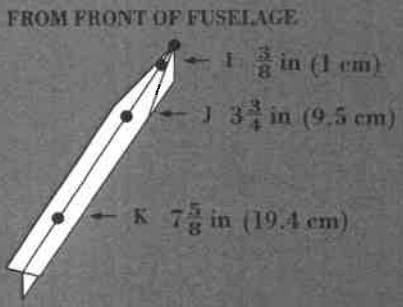


STEP 15 Cut piece F to size for the ventral fins, as shown. Mountain fold in half vertically. Unfold. On each side, mountain fold in half vertically so that outer edge meets center crease. Unfold. On each side, measure and cut, as shown by heavy line. Then cut in two along center crease.

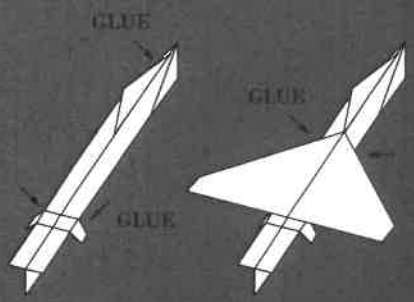
CANOPY (type 2)
$1\frac{1}{4}$ in x $3\frac{1}{2}$ in (3.1 cm x 8.75 cm)
Top point 2 in (5 cm)

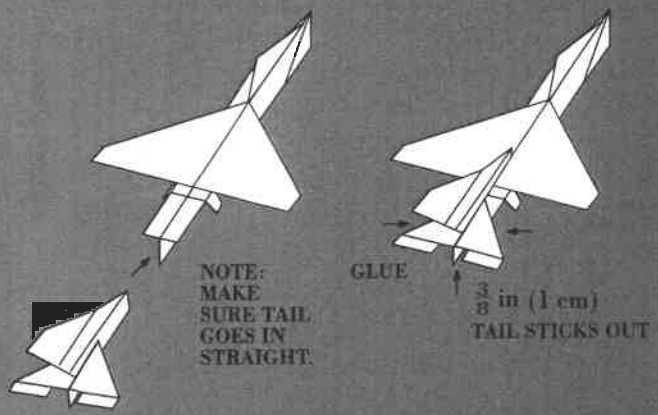
STEP 16 Use piece E to make the canopy. (See p 28.)

STEP 17 Measure from front of fuselage and make marks for positioning the leading edges of canopy at I, wings at J, ventral fins at K.

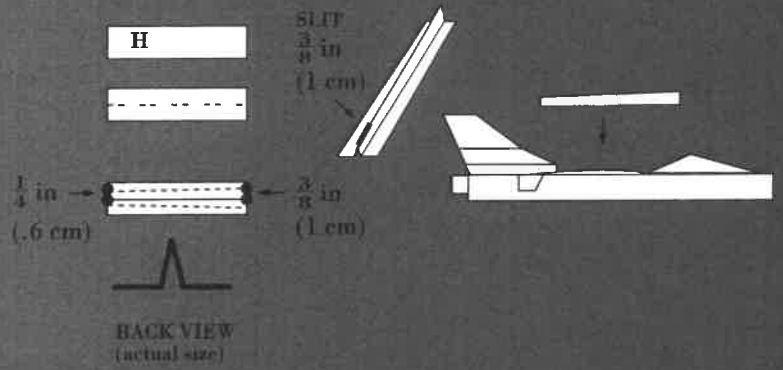


STEP 18 Apply glue to inside of nose and the small tabs on the bottom of the canopy. Slide canopy in place. Hold until glue sets. Next, glue ventral fins in place. Then glue wings in place overlapping ventral fins, as shown.

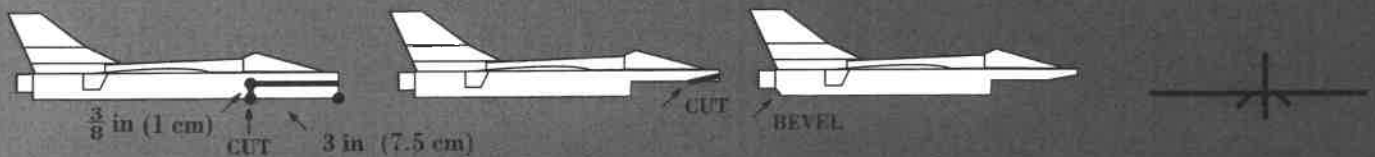




STEP 19 Apply glue and slide tail into fuselage. The tail sticks out of the back end of fuselage, with the vertical tail sliding into slit in the wings.

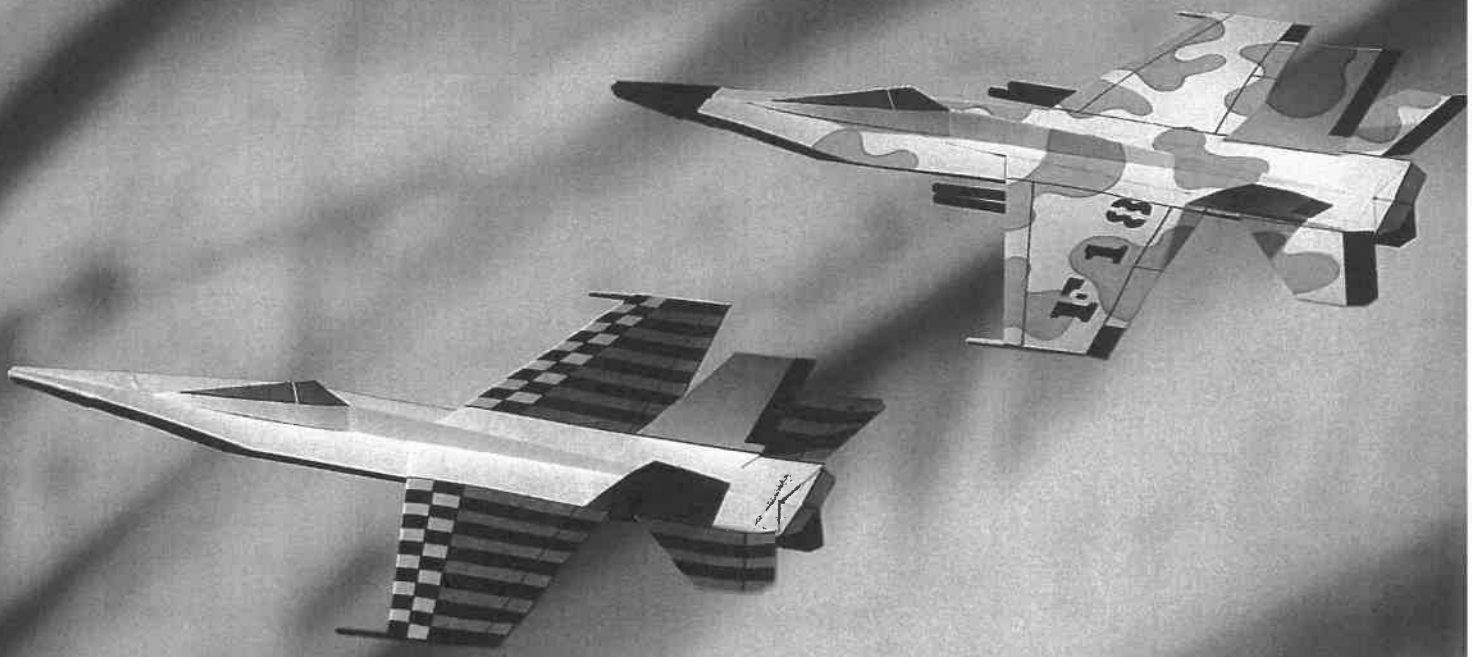


STEP 20 Use piece H to make the top of the fuselage. Mountain fold in half horizontally. Unfold. On each side of crease, measure and valley fold, as shown. Make slit. Glue onto top of fuselage, as shown. The vertical tail slides into slit. Fit the front snuggly over back of canopy.



STEP 21 Measure and cut nose, as shown. First cut a rectangular notch, then cut the tip diagonally to give final shape to the nose. Bevel back of fuselage. This plane has no dihedral. Ventral fins are canted (slanted) 45°.

F18 Hornet

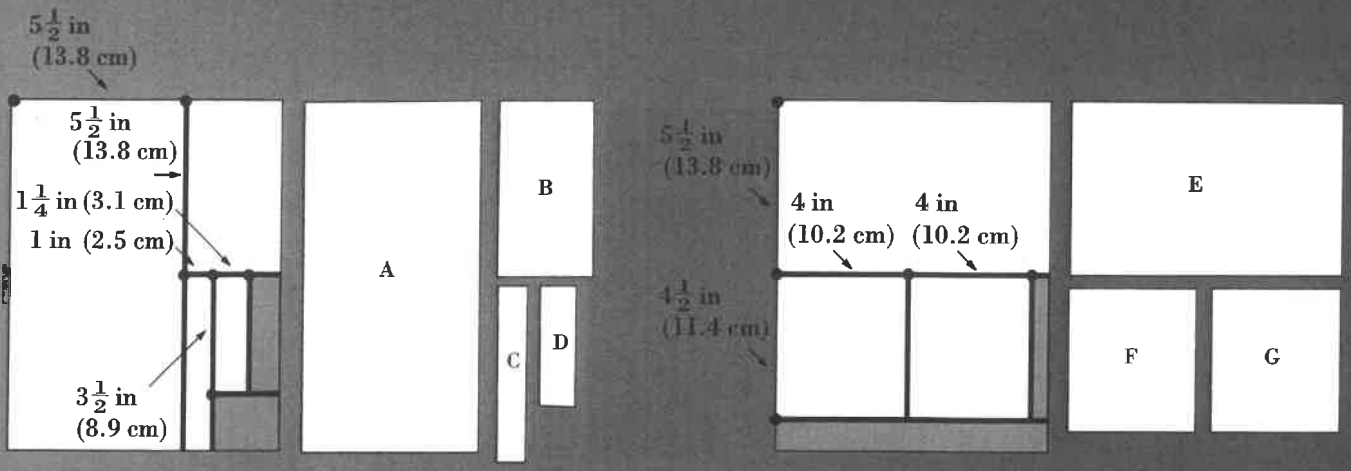


HISTORICAL INFORMATION

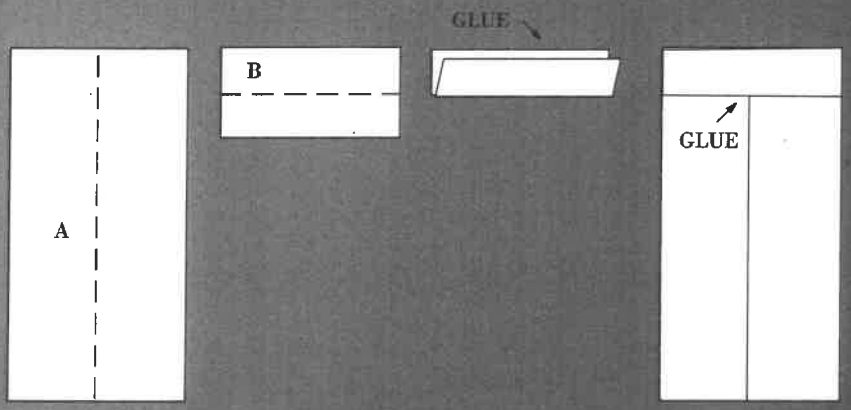
The F16 was used as a land-based fighter aircraft but there was no equivalent sea-based fighter. Therefore the F18 was built in the early 1980s as a medium sized multi-task maneuverable military aircraft capable of both sea and land operations. This plane is commonly called the "Hornet." It has tapered wings and a conventional horizontal tail, but with two canted (tilted) vertical tails located between the wings and horizontal tail. The F18 is used by the USA, Canada, Australia, and Spain. This paper airplane is modeled on the F18.

The F18 is constructed mostly of aluminum, with parts of its wings and other surfaces made of composites. It has two afterburning turbojet engines that can propel it at almost twice the speed of sound when traveling at high altitude. This airplane is both a fighter and an attack plane, and it can be fitted with a wide variety of armament for both air-to-air and air-to-ground military tasks. Like the F16, it has a missile rail at each wingtip, with space under the wings for other armament and extra fuel tanks. Besides its military role, this plane is also used as an aerial display airplane at air shows.

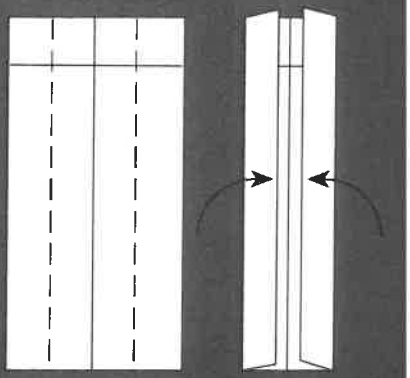
Making the F18



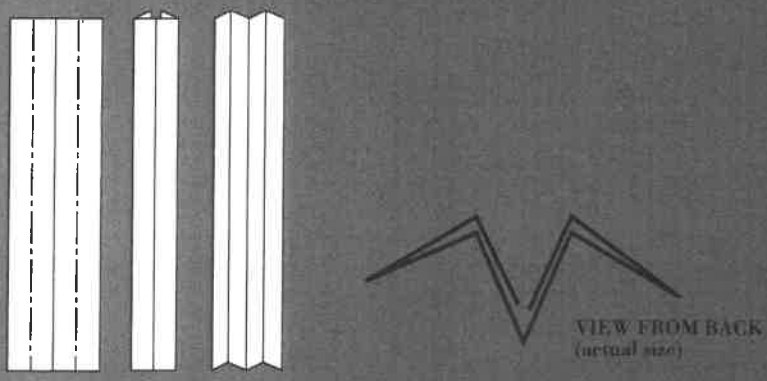
STEP 1 Measure and cut the various pieces from two sheets of bond paper.



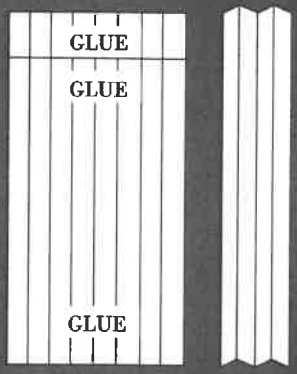
STEP 2 Use piece A to make the fuselage. Fold in half vertically using a valley fold. Unfold. Then valley fold piece B in half horizontally to make nose ballast. Glue halves together. Glue B to A, aligning top edges, as shown.



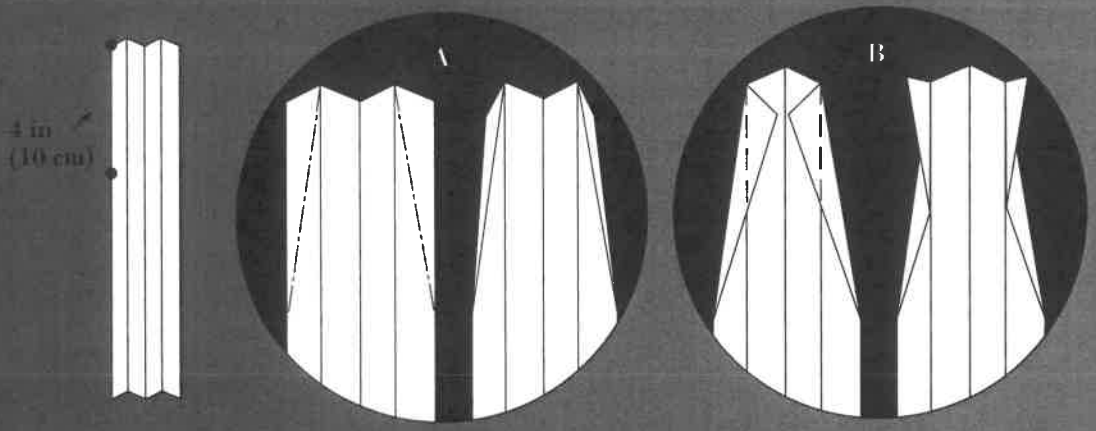
STEP 3 Valley fold so that outer edges meet center crease.



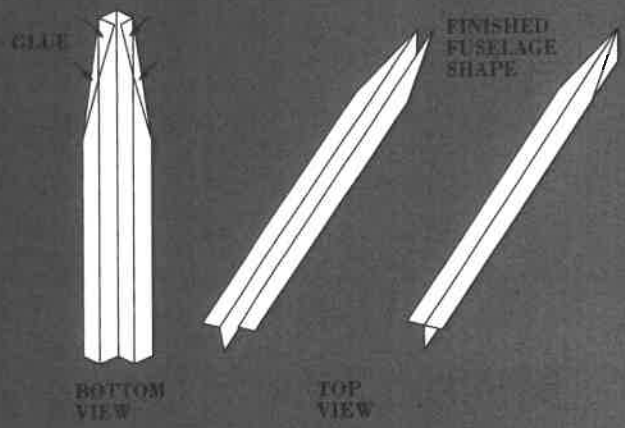
STEP 4 Fold each side again using a mountain fold, so that outer edges meet center crease at back. Then adjust folds so that paper looks like an upside-down W, as shown.



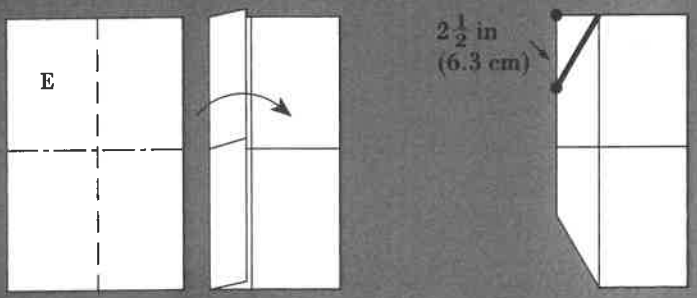
STEP 5 Unfold fuselage completely. Refold applying glue to contacting surfaces, as shown. Make sure fuselage is straight.



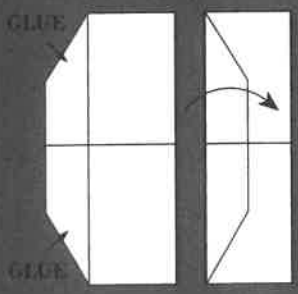
STEP 6 On each side, measure from top (front of fuselage), mark, and mountain fold along broken lines, as shown in enlarged view A. Then flip over fuselage. On each side, valley fold the triangle along the broken lines, matching fold line to existing crease, as shown in enlarged view B.



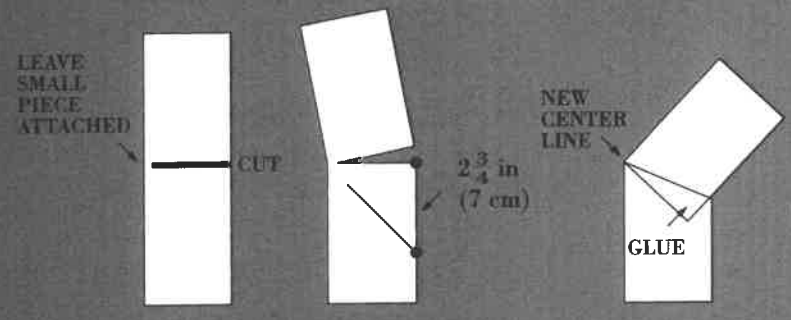
STEP 7 Glue triangles. Hold in place until glue sets. It is important that the fuselage stays straight. Do not glue nose yet.



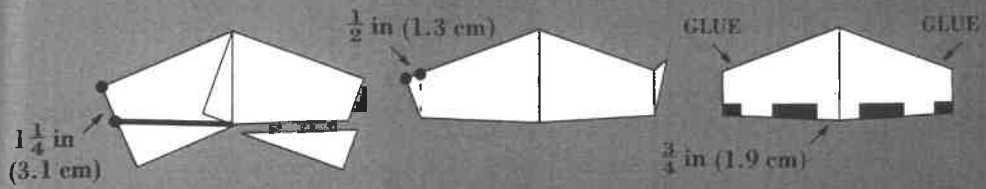
STEP 8 Lay piece E in a vertical direction to make wings. Valley fold in half vertically. Unfold. Mountain fold in half horizontally. Valley fold so that one outer edge meets center crease, as shown. On each side of horizontal center crease , measure and cut diagonally, as shown by heavy line.



STEP 9 Apply glue to each diagonal side on top layer only, no more than 1 in (2.5 cm) from the diagonal edge. Refold along the original vertical center crease. The folded-over part is the bottom of the leading edge (front) of wings.



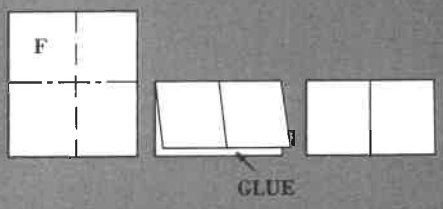
STEP 10 To taper wings, cut along center line from the trailing edge (back), leaving a small piece attached at the leading edge. Then measure and draw diagonal line, as shown. Align halves to the diagonal line. Glue. Draw new center line.



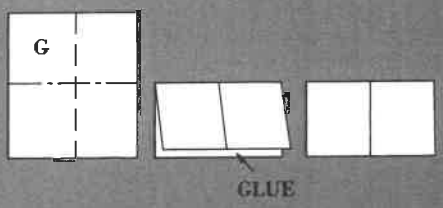
AILERONS
$\frac{1}{2}$ in x $\frac{1}{4}$ in
(1.3 cm x .6 cm)

FLAPS
$1\frac{1}{4}$ in x $\frac{1}{4}$ in
(3.1 cm x .6 cm)

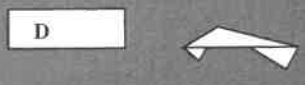
STEP 11 On each side, measure and cut trailing edge, as shown by heavy line. Then on each side, measure and mountain fold wingtips. Glue. Make ailerons and flaps in locations shown.



STEP 12 Lay piece F flat in a vertical direction to make the horizontal tail. Valley fold in half vertically. Unfold. Mountain fold in half horizontally. Glue halves together.



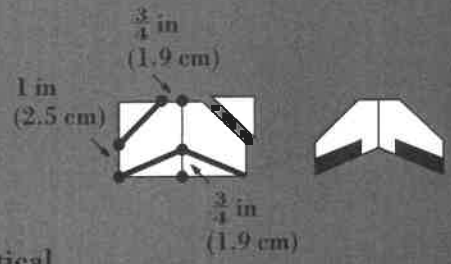
STEP 14 Lay piece G flat in a vertical direction to make the twin vertical tails. Valley fold in half vertically. Unfold. Mountain fold in half horizontally. Glue halves together.



CANOPY (type 2)
$1\frac{1}{4}$ in x $3\frac{1}{2}$ in (3.1 cm x 8.9 cm)
Top point $2\frac{1}{2}$ in (6.4 cm)

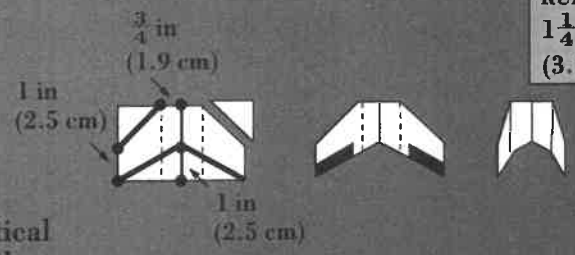
STEP 16 Use piece D to make the canopy (see p 28).

ELEVATORS
$1\frac{1}{4}$ in x $\frac{3}{8}$ in
(3.1 cm x 1 cm)

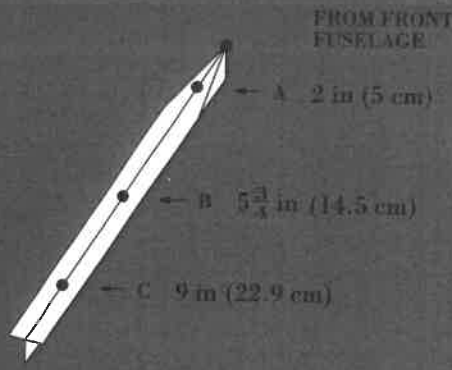


STEP 13 On each side, measure and cut, as shown by heavy lines. Make elevators.

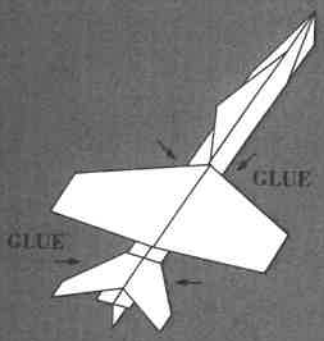
RUDDERS
$1\frac{1}{4}$ in x $\frac{1}{4}$ in
(3.1 cm x .6 cm)



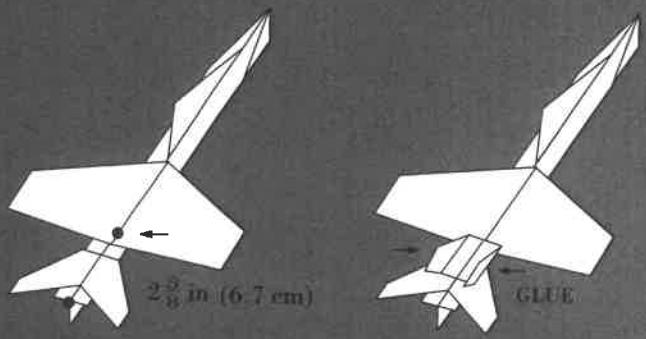
STEP 15 On each side, measure and cut, as shown by heavy lines. Make a rudder on each vertical tail. On each side, valley fold, as shown.



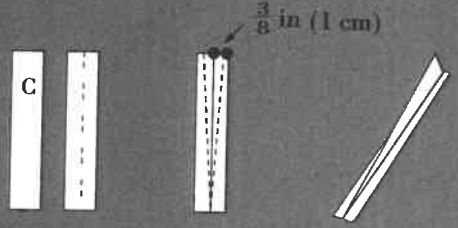
STEP 17 Measure from front of fuselage, as shown, and make mark A for positioning the front of the canopy, mark B for positioning leading edge of the wings, and mark C for positioning leading edge of the horizontal tail.



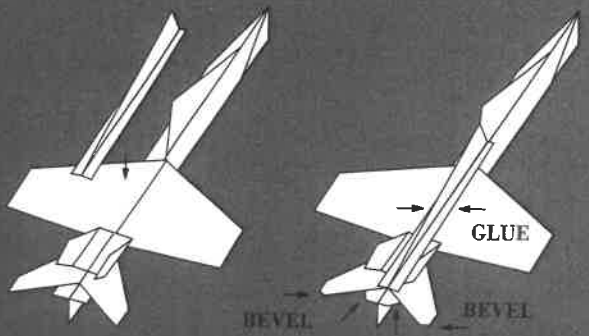
STEP 18 Apply glue to the inside of the nose and the small triangles on the bottom of the canopy. Position canopy on the fuselage at mark A. Hold until glue sets. Glue wings and horizontal tail in place, making sure they are centered and at right angles to the fuselage.



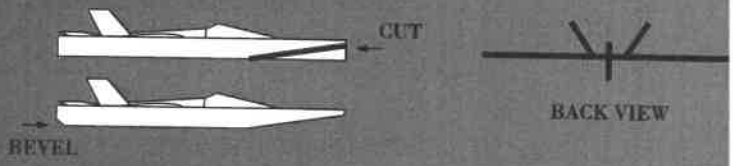
STEP 19 Measure from back of fuselage, as shown, and make a mark for positioning the twin vertical tails. Glue vertical tails in place, making sure they are centered and parallel to the fuselage.



STEP 20 Lay piece C in a vertical direction to make the fuselage top. Mountain fold in half vertically. Unfold. On each side, measure and valley fold. Adjust shape, as shown.

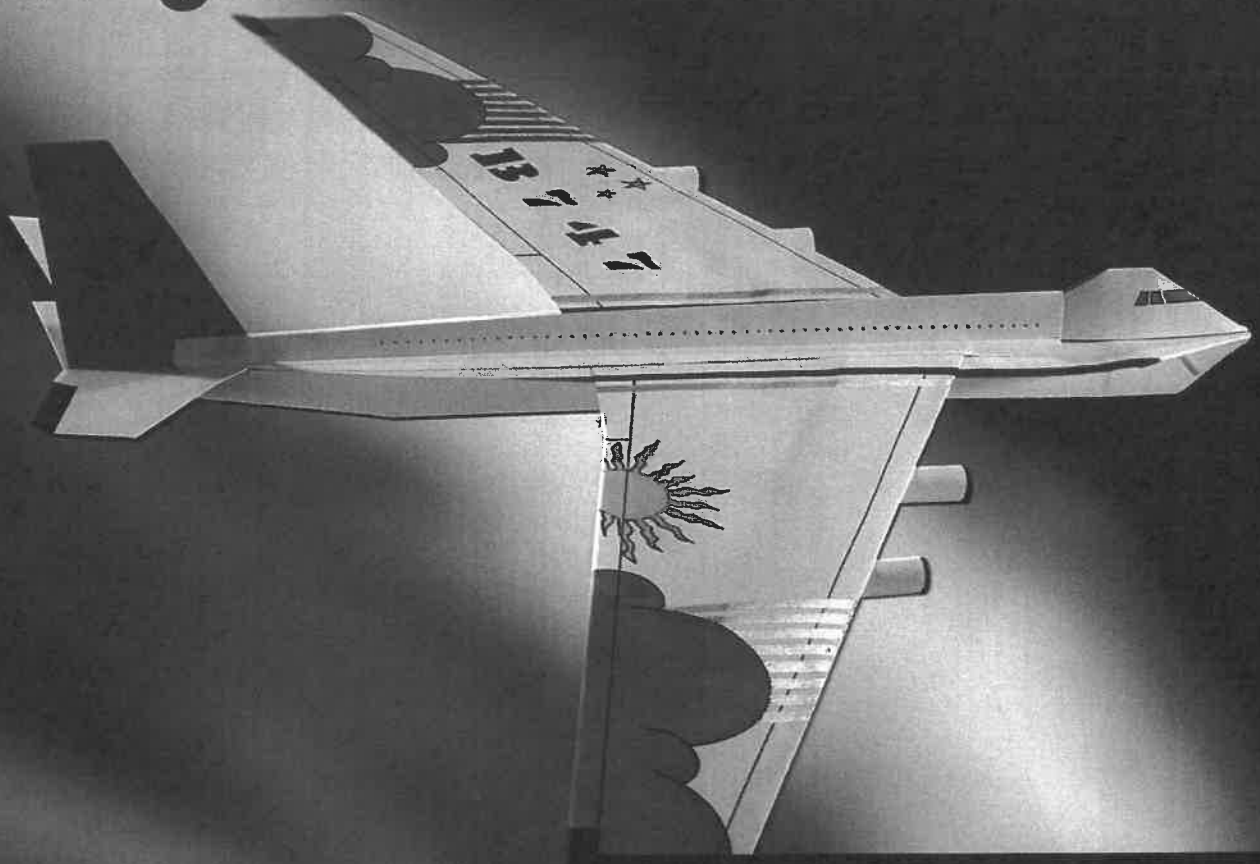


STEP 21 Glue piece C onto the fuselage, making sure it fits snugly against the canopy. Bevel the trailing edges of the elevators.



STEP 22 Measure and cut nose diagonally, as shown by heavy line. Bevel all corners of the back of the fuselage. Wings and horizontal tail are level. Adjust angles of the canted (tilted) vertical tails, as shown.

747 Jumbo

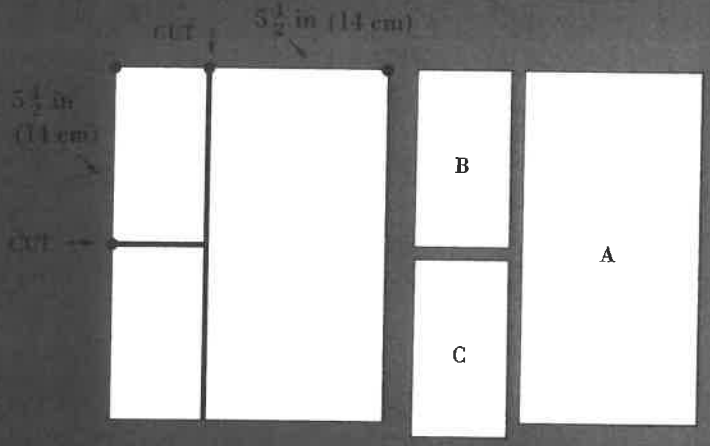


HISTORICAL INFORMATION

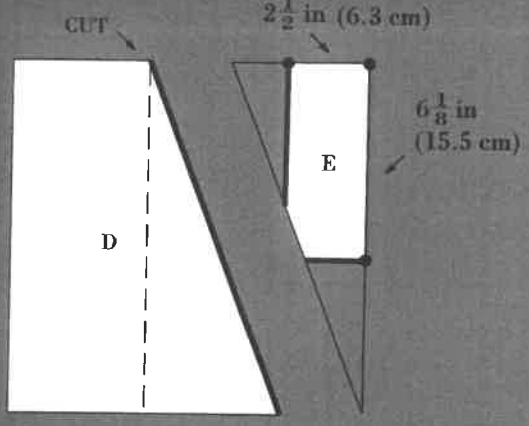
The first jet-powered airliner was the deHavilland Comet built in the 1950s. As more and more people realized the comfort of jet travel, bigger airplanes were needed to carry them. The Boeing 747 was first built in 1968. It is one of the largest passenger-carrying airplanes in the world. It is longer than the distance flown by the Wright brothers (120 ft or 36 m)) in their first powered flight. The "Jumbo Jet" is used to carry passengers and cargo across the continents and the oceans of the world. This paper airplane is modeled on the 747.

The Boeing 747 is a big airplane. From nose to tail it measures 230 ft (69 m). The distance from wingtip to wingtip is 195 ft (58.5 m). Its tail is 64 ft (19 m) high, higher than a five storey building. When it is fully loaded with fuel, passengers, and cargo, it weighs 800,000 lb (360,000 kg), and carries 500 passengers or 270,000 lb (121,500 kg) of cargo. Once it reaches high altitude, it cruises at 600 mph (960 km/h). This makes it ideal for use on long-distance passenger routes. Its service ceiling is 40,000 ft (12,000 m) above the ground. Its maximum range is 6000 miles (9600 km), allowing it to fly one fourth of the distance around the earth without refueling. The plane is propelled by four 50,000 lb thrust turbofan jet engines.

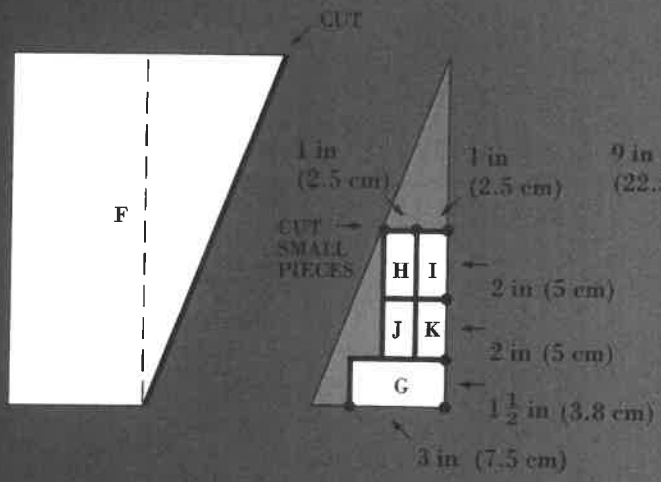
Making the 747



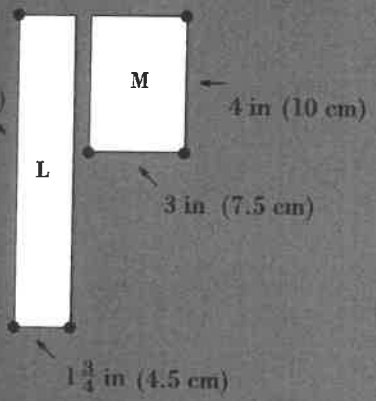
STEP 1 Measure and cut three pieces from a sheet of bond paper, as shown.



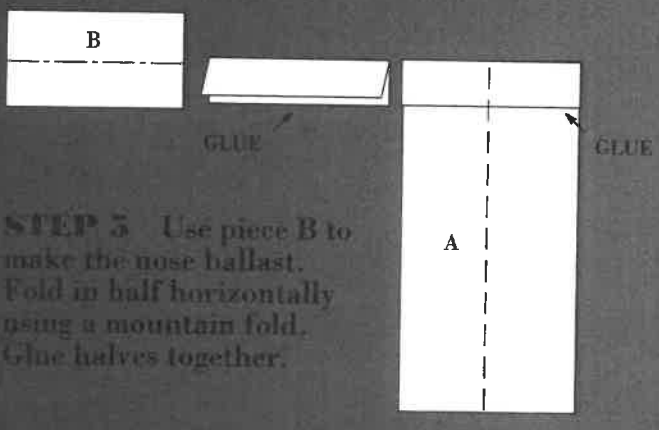
STEP 2 Valley fold a second sheet of bond paper in half vertically. Then measure and cut two pieces, as shown.



STEP 3 Valley fold a third sheet of bond paper in half vertically. Then measure and cut six pieces, as shown.

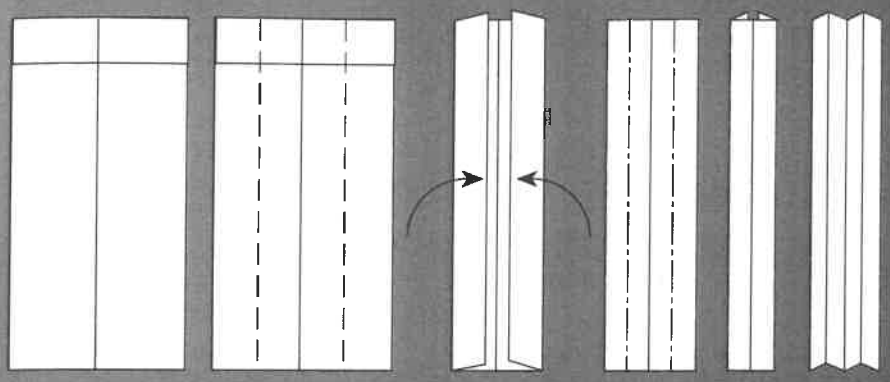


STEP 4 Measure and cut two additional pieces, as shown.



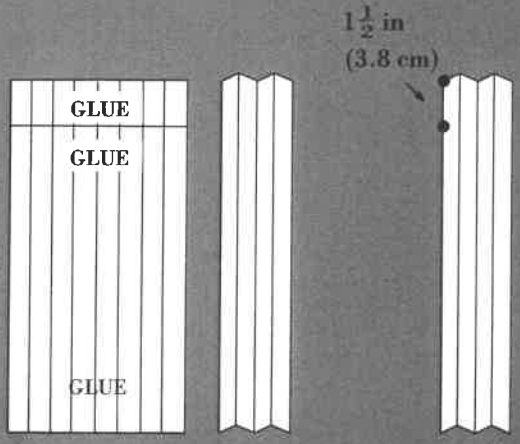
STEP 5 Use piece B to make the nose ballast. Fold in half horizontally using a mountain fold. Glue halves together.

STEP 6 Use piece A to make the fuselage. Glue ballast to the top of fuselage, as shown. Fold in half vertically using a valley fold. Unfold.

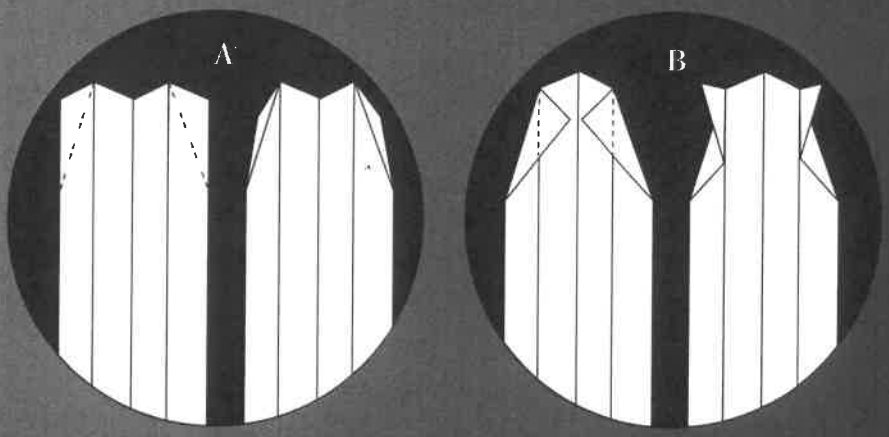


STEP 7 Valley fold each side so that outer edges meet center crease, as shown.

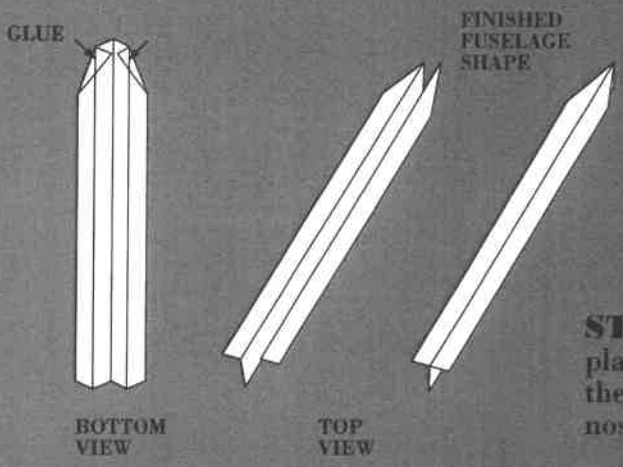
STEP 8 Fold each side again using a mountain fold, so that outer edges meet center crease at back. Then adjust folds so that paper looks like an upside-down W, as shown.



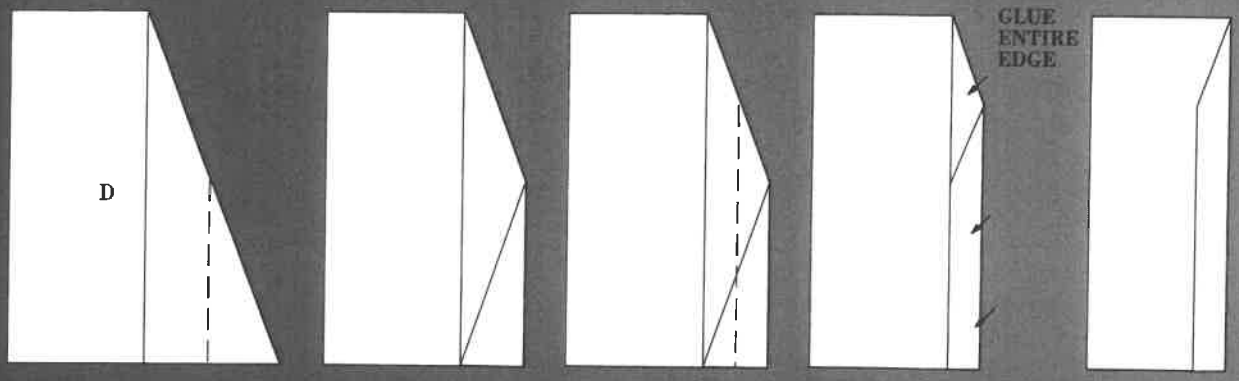
STEP 9 Unfold fuselage completely. Refold applying glue to contacting surfaces, as shown. Make sure fuselage is straight.



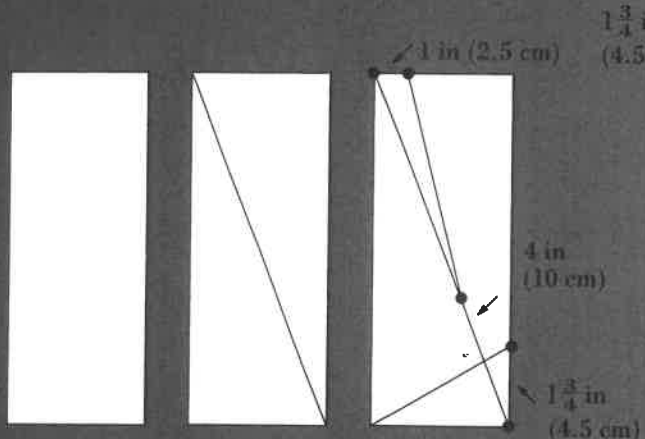
STEP 10 On each side, measure from top (front of fuselage), mark, and mountain fold along broken lines, as shown in enlarged view A. Then flip over fuselage. On each side, valley fold triangle along broken lines, matching fold line to existing crease, as shown in enlarged view B.



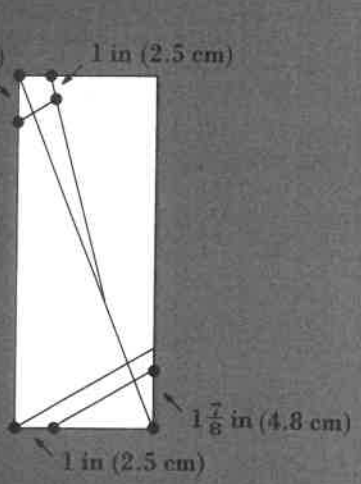
STEP 11 Glue triangles. Hold in place until glue sets. It is important that the fuselage stays straight. Do not glue nose yet.



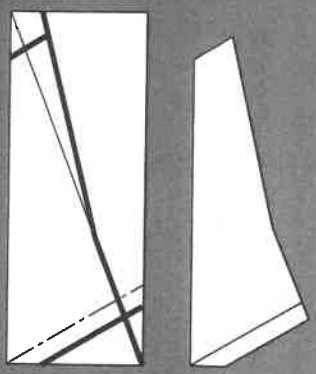
STEP 12 Lay piece D vertically to make the right wing. Valley fold vertically so that bottom outer edge meets center crease. Valley fold vertically again so that outer edge meets center crease. Apply glue. Then fold over again along original vertical center crease.



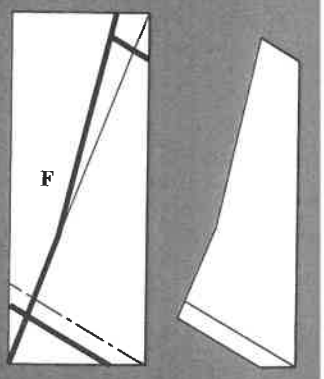
STEP 13 Flip over, with folded-over edge to the LEFT. Draw diagonal line from upper left to lower right corners. Measure along line from bottom and make a mark. Measure along top edge from left and mark. Join the two marks. Then measure along right edge from bottom and mark. Join this point with the bottom left corner.



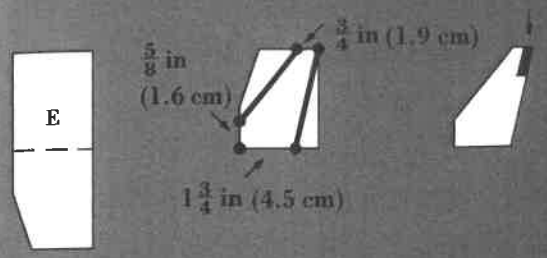
STEP 14 Measure along left edge from top and make a mark. Measure along line from top, as shown, and make a mark. Join the two marks. Then measure along bottom edge from left and make mark. Measure along right edge from bottom and make a mark. Join marks.



STEP 15 Cut along heavy lines, as shown. Then mountain fold along line, as shown.

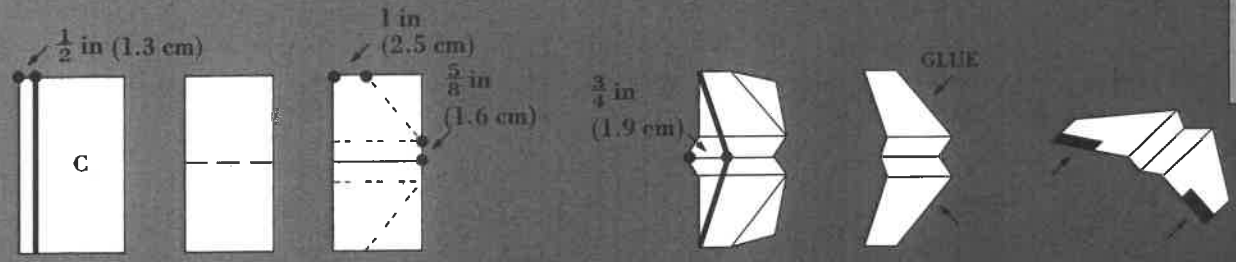


STEP 16 To make the left wing, repeat steps 12-15 using piece F, keeping the folded edge on the RIGHT and reversing the directions of the lines from left to right, as shown.



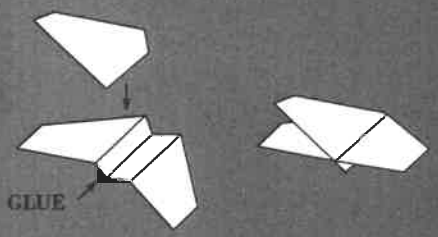
RUDDER
1 in x 1/4 in (2.5 cm x .6 cm)

STEP 17 Lay piece E vertically to make the vertical tail. Valley fold in half horizontally and glue halves together. Then cut along heavy lines, as shown. Make rudder on trailing edge.

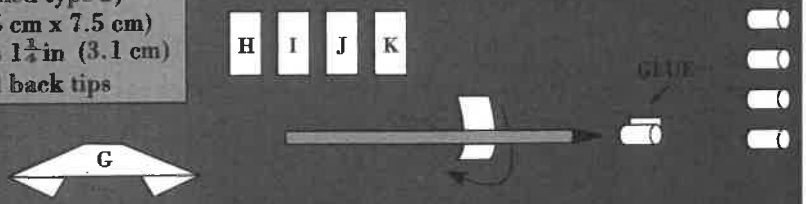


ELEVATORS
1 1/4 in x 1/4 in (3.1 cm x .6 cm)

STEP 18 Lay piece C vertically to make the horizontal tail. Measure and cut to size. Valley fold in half horizontally. Unfold. On each side, measure from center crease, as shown, and mountain fold. On each side, measure and mountain fold leading edge along broken lines. Glue. Cut trailing edges and make elevators.

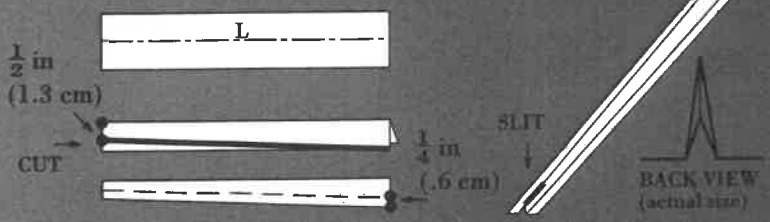


CANOPY (Modified type 2)
1 in x 3 in (2.5 cm x 7.5 cm) with top points 1 1/4 in (3.1 cm) from front and back tips

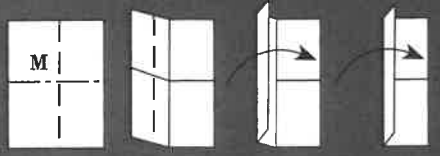


STEP 19 Apply glue to inside of horizontal tail and insert vertical tail, aligning leading (front) edges.

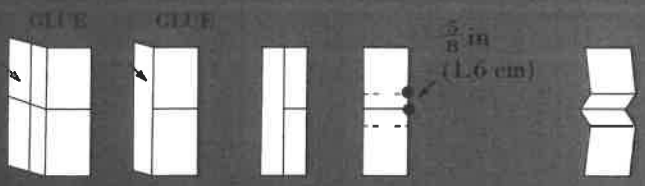
STEP 20 Use piece G to make the canopy (see p 28). Use pieces H, I, J, and K to make the engines. Wrap each piece around a pencil vertically and glue.



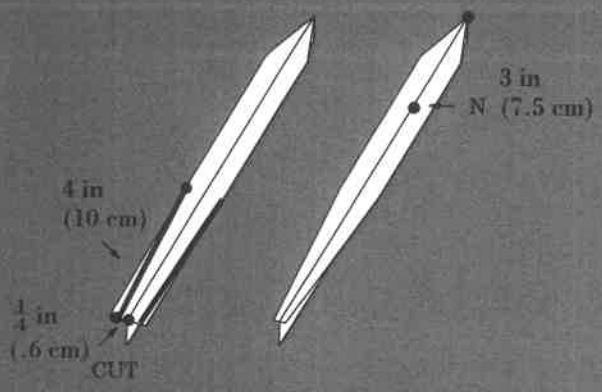
STEP 21 Use piece L to make the top of the fuselage. Mountain fold in half horizontally. Then, on each side, measure and valley fold to form piece, as shown. Cut a 1 in (2.5 cm) slit along center crease at narrow end.



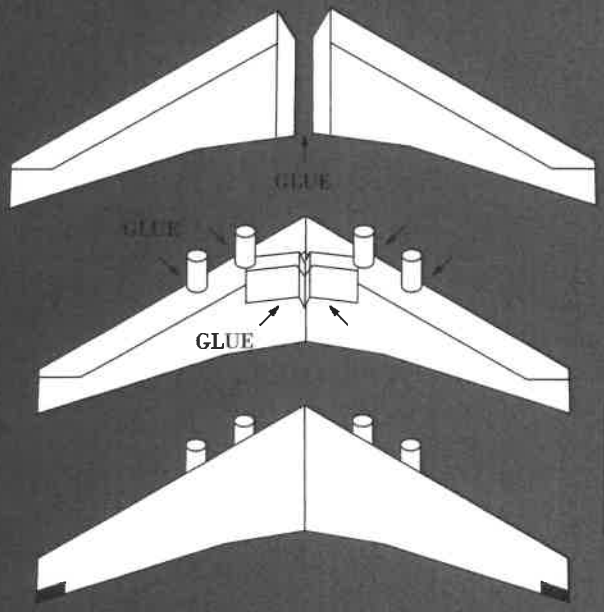
STEP 22 Use piece M to make a spar (support) for the wings. Valley fold in half vertically. Unfold. Mountain fold in half horizontally. Unfold. Then valley fold vertically so that outer edge meets center crease. Fold over again along original vertical center crease.



STEP 23 Unfold spar completely. Refold, applying glue to contacting surfaces. Flip over. On each side of center crease, measure and mountain fold, as shown. Folded over edge is the front.

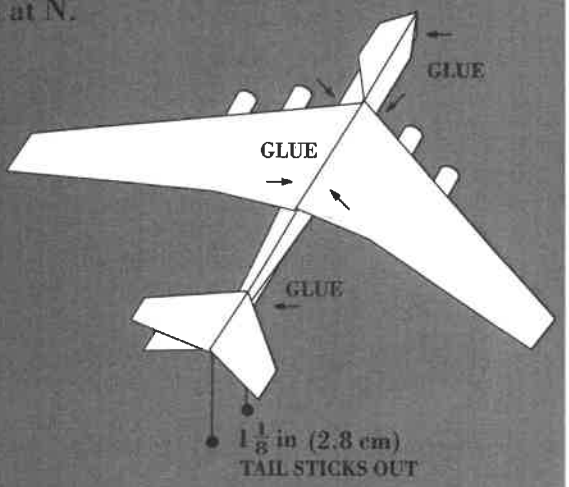


STEP 24 Measure back of fuselage and cut, as shown. Then measure from front and make mark for positioning leading edge of wings at N.

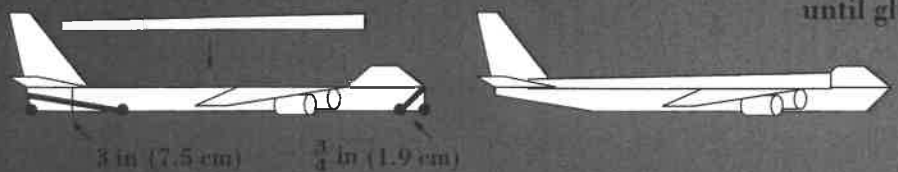


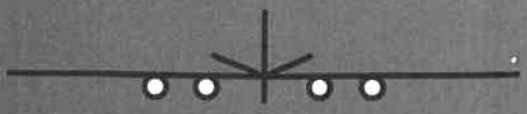
AILERONS
$\frac{3}{4}$ in x $\frac{1}{4}$ in
(1.9 cm x .6 cm)

STEP 25 With wings upside down, glue halves together. Glue spar to wings. Glue engines to wings in approximate positions shown (they stick out $\frac{1}{2}$ in (1.3 cm). Flip over. On trailing edges, make ailerons.

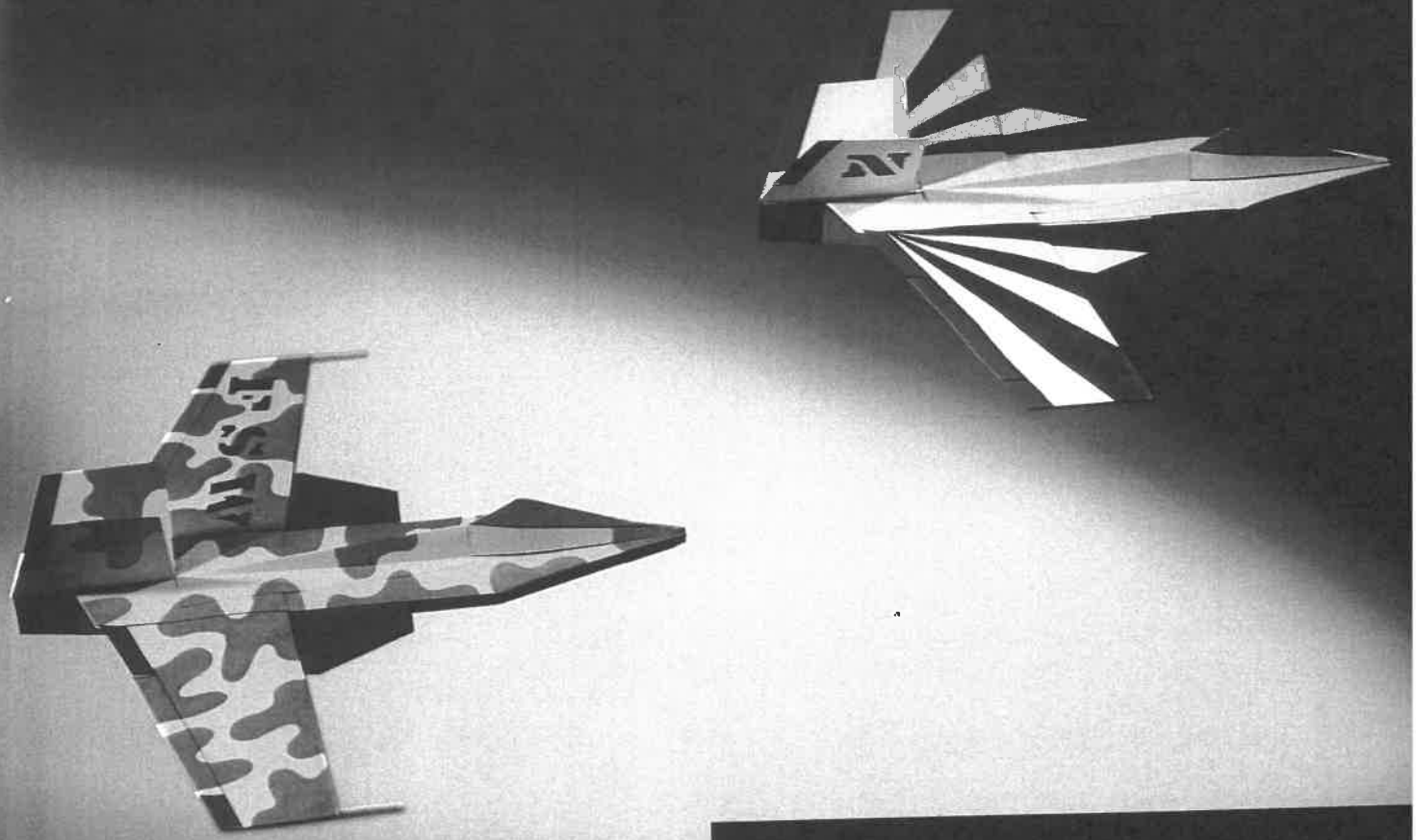


STEP 26 Apply glue to inside of fuselage, the small triangles on the bottom of canopy, and the center bottom of wings. Slide canopy tabs into fuselage aligning with front tip. Immediately slide wings in place. Then apply glue and slide tail into back of fuselage. Hold until glue sets.





STEP 27 Measure and cut nose and tail ends diagonally along heavy lines, as shown. Glue L onto top of fuselage, as shown, fitting snuggly against back of canopy, with vertical tail through the slit. Adjust dihedral (upward slanting of wings and tail), as shown.

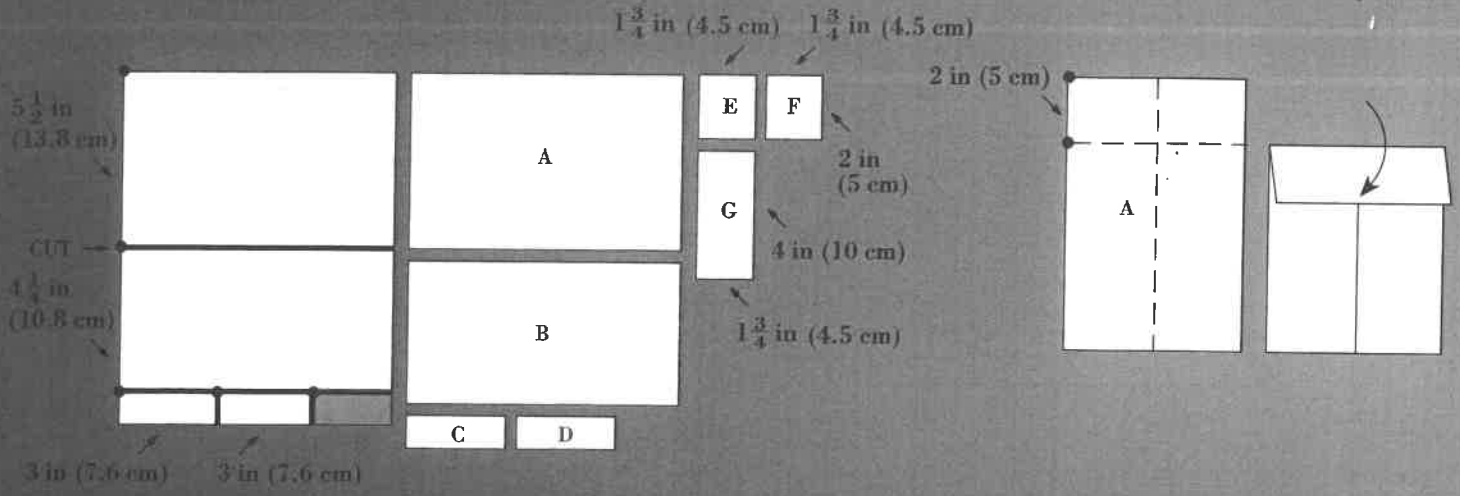


HISTORICAL INFORMATION

Airplane builders are always trying to make planes that are more suited to special tasks. In the 1980s a new shape of airplane appeared. Grumman introduced the X29 forward swept wing (FSW) experimental airplane, using new composite materials that were very light and strong. Such a design was impossible to build with traditional materials. The advantages of sweeping the wings forward instead of backward allow for maneuverability and high angle of attack flight — desirable qualities for military application. This paper airplane is modeled on a forward swept wing aircraft that has not yet been built. This concept, designed by Grumman, is being considered for possible future development.

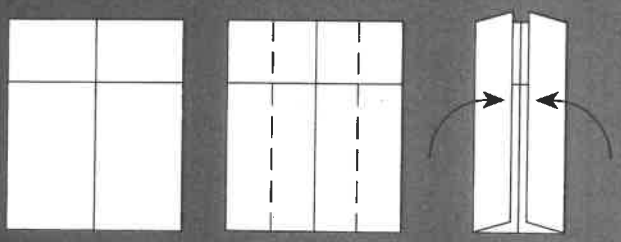
A future fighter will have to operate over a wide ran of speeds, be very maneuverable, and be fuel efficien It will have to be able to land in very small spaces. Forward swept wings combined with strakes (extensio of the leading edges near the fuselage) will improve t flight characteristics of the plane at very low and ve high speeds. However, having no horizontal tail mak the plane sensitive to correct balance, and compute will aid in control. The light weight of composites, th lack of a horizontal tail, and better engines will allo improved fuel efficiency. The FSW Concept will probably have two turbojet engines and be able to f at more than twice the speed of sound at high altitud Its air intakes will be part of the large strakes. The plane will have a missile rail at each wingtip, and be able to carry extra fuel tanks and a variety of armament under the wings. Like present day fighter this craft will be used for both air-to-air and air-to-ground operations. Besides its military role, this airplane could be a good candidate for aerial displa at air shows.

Making the FSW Concept

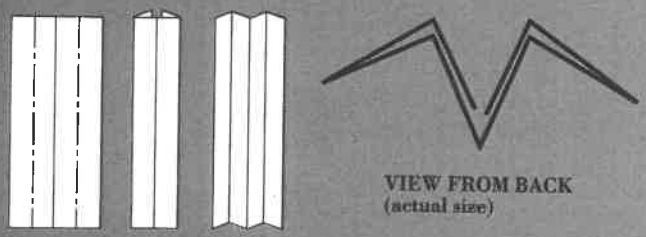


STEP 1 Measure and cut pieces from a sheet of bond paper. Three additional pieces, E, F, and G are needed, as shown.

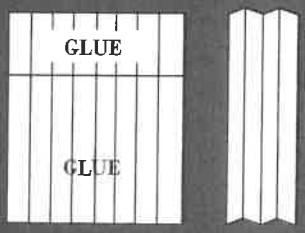
STEP 2 To make the fuselage, lay piece A in a vertical direction. Fold in half vertically, using a valley fold. Unfold. Measure from top and valley fold, as shown.



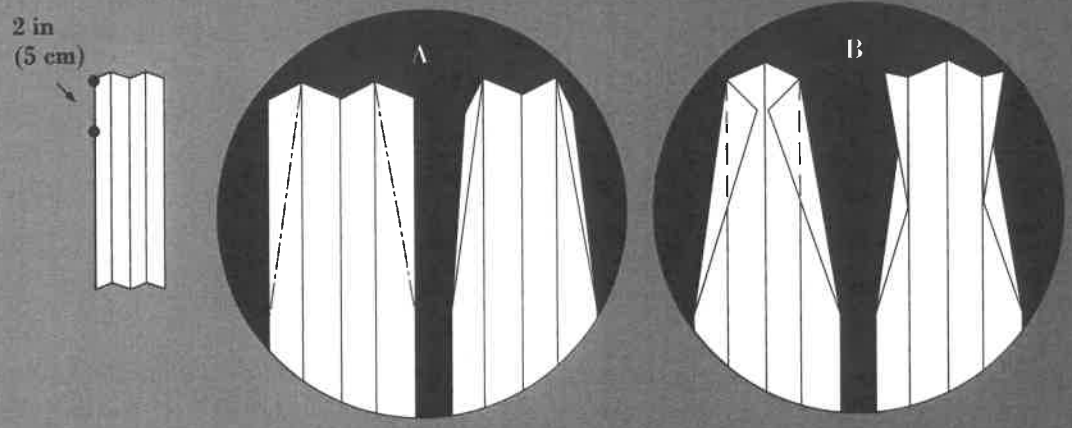
STEP 3 Valley fold each side so that outer edges meet center crease, as shown.



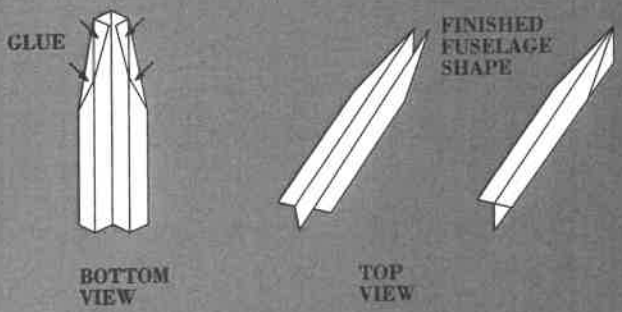
STEP 4 Fold each side again using a mountain fold, so that outer edges meet center crease at back. Then adjust folds so that paper looks like an upside-down W, as shown.



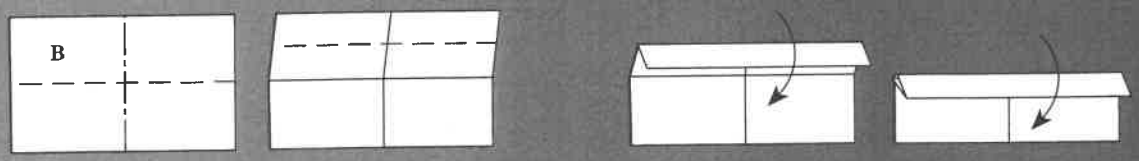
STEP 5 Unfold fuselage completely. Refold applying glue to all contacting surfaces, as shown. Make sure fuselage is straight.



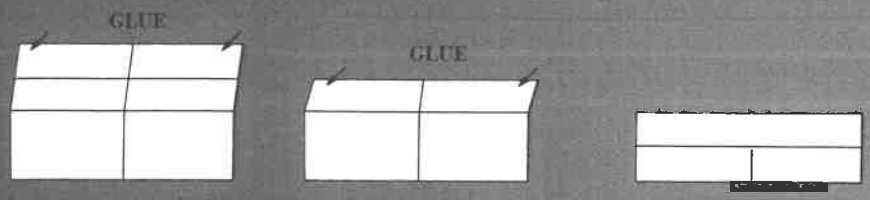
STEP 6 On each side, measure from top (front of fuselage), mark, and mountain fold along broken lines, as shown in enlarged view A. Then flip over fuselage. On each side, valley fold triangle along broken lines, matching fold line to existing crease, as shown in enlarged view B.



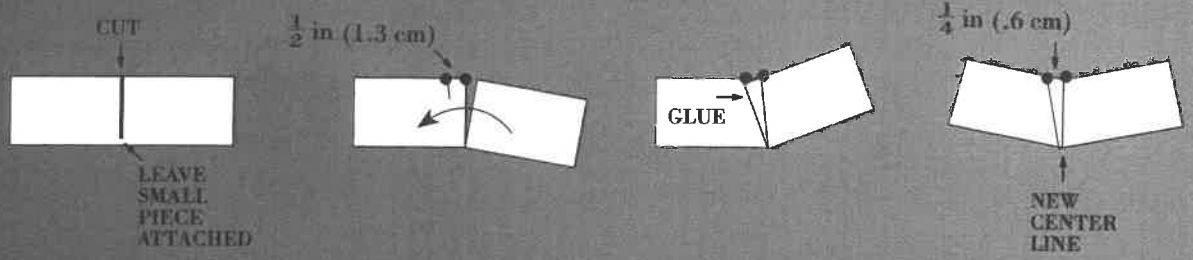
STEP 7 Glue triangles. Hold in place until glue sets. It is important that the fuselage stays straight. Do not glue nose yet.



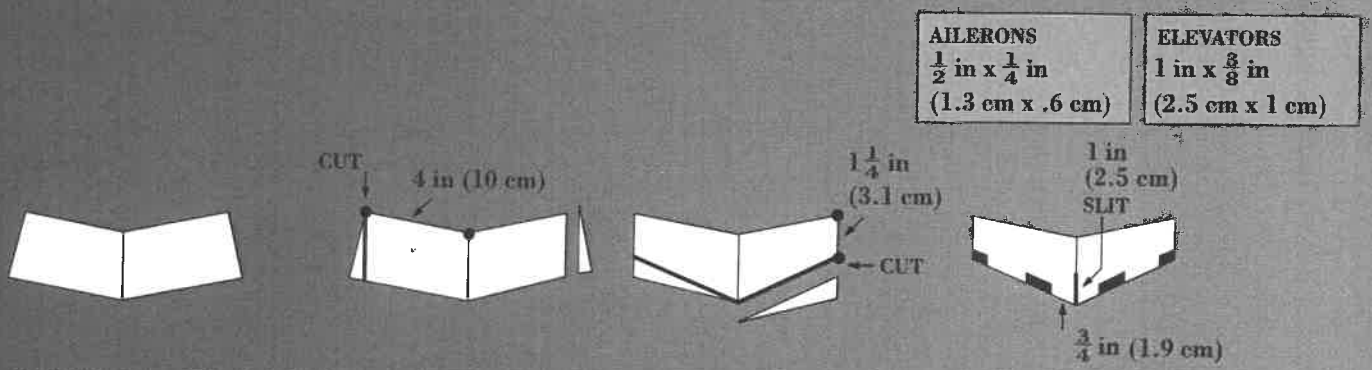
STEP 8 Use piece B to make the wings. Lay paper in a horizontal direction and fold in half vertically, using a mountain fold. Unfold. Valley fold in half horizontally. Unfold. Then valley fold horizontally so that top edge meets center crease. Fold over again along original center crease.



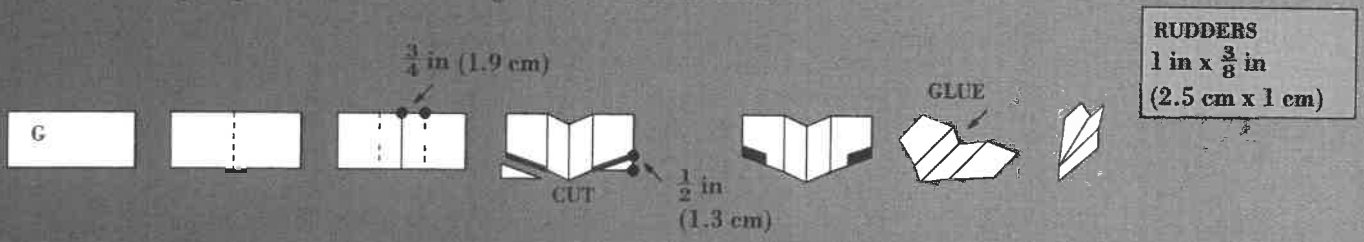
STEP 9 Unfold completely. Refold, applying glue to no more than 1 in (2.5 cm) from outer tips, as shown. The folded over part is the bottom of the leading edge (front) of the wings.



STEP 10 To sweep wings forward, cut along center line from the leading edge, leaving a small piece attached at the trailing edge (back). Then measure and make a mark on leading edge, as shown. Align pieces to the mark. Glue. Measure and draw new center line.



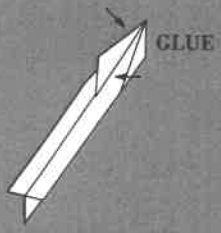
STEP 11 To finish forward swept wings, measure and cut wing tips along heavy lines. Then cut trailing edge along heavy lines, as shown. On trailing edges (back), make ailerons and elevators. From trailing edge, make a slit along center line, as shown.



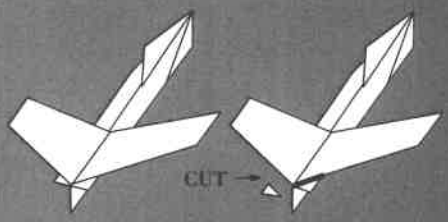
STEP 12 Use piece G to make the twin vertical tails. Lay paper in a horizontal direction. Valley fold in half vertically. Unfold. On each side, measure from center crease and mountain fold, as shown. Then measure and cut trailing edges, as shown by heavy lines. Make rudders. Glue center.

CANOPY (type 2)
$1\frac{1}{4}$ in x 3 in (3.1 cm x 7.5 cm)
Top point $1\frac{3}{4}$ in (4.5 cm)

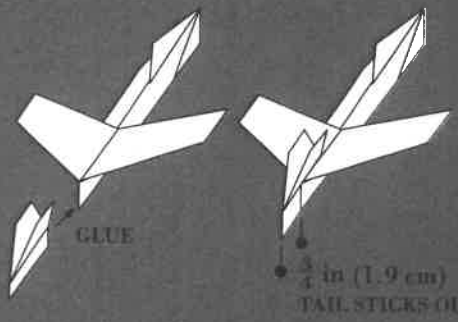
STEP 13 Use piece C to make a type 2 canopy (see p 28).



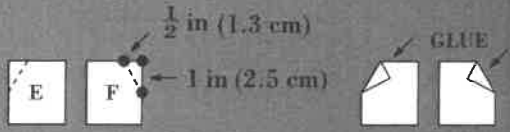
STEP 14 Apply glue to inside of nose and the small triangular tabs on the bottom of canopy. Slide tabs into fuselage, aligning canopy with the tip of the nose. Hold until glue sets.



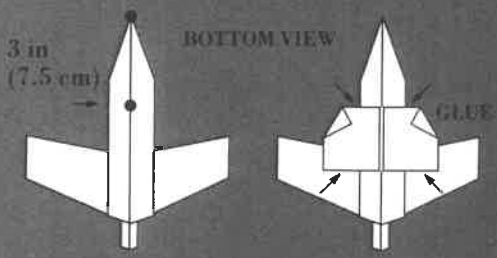
STEP 15 Glue wings in place, aligning at the trailing (back) edge. Make sure they are centered and at right angles to the fuselage. Trim fuselage back flush with the wing trailing (back) edges.



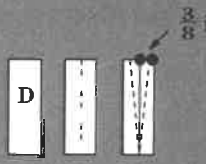
STEP 16 Measure and mark along bottom of tail. Apply glue and slide tail into back of fuselage (and slit in the wings) to the mark.

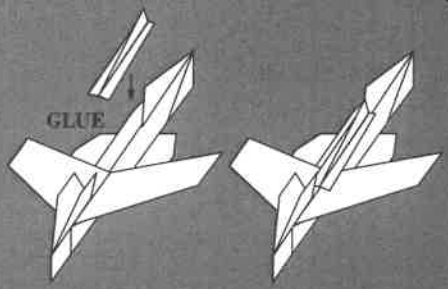


STEP 17 Use pieces E and F to make the strakes. Lay pieces vertically side by side, as shown. Measure on outer left and right edges and valley fold diagonally, as shown. Glue.

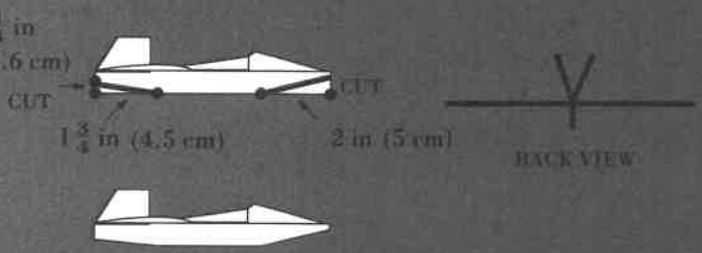


STEP 18 Turn airplane over. Measure from front and mark, as shown. On each side, glue strakes in place, aligning inside corners to the mark.

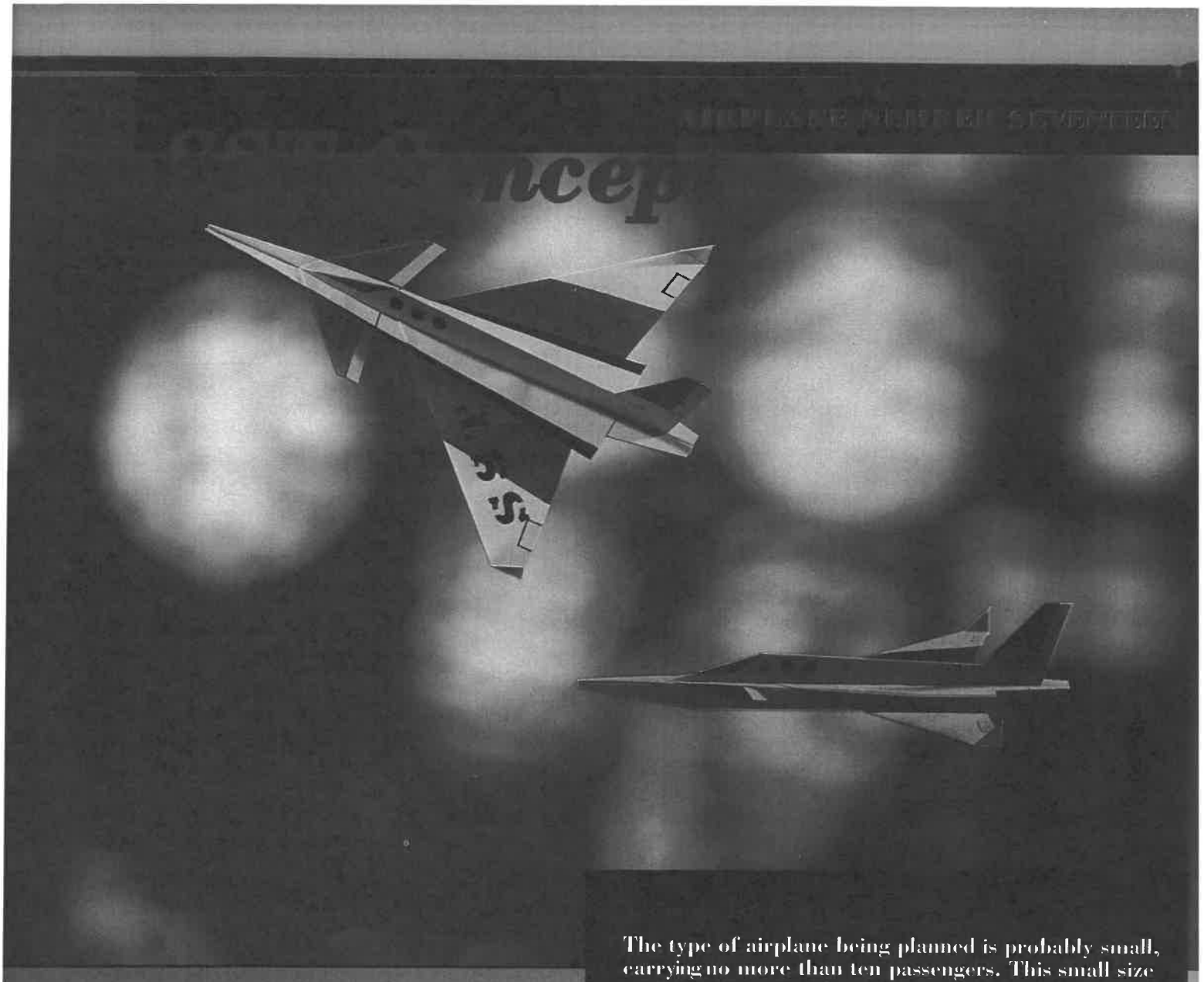




STEP 19 Lay piece D in a vertical direction to make the fuselage top. Mountain fold in half vertically. Unfold. On each side, measure and valley fold. Adjust shape, as shown. Glue onto top of fuselage, as shown, fitting the front snuggly over back of canopy.



STEP 20 Measure and cut nose and tail diagonally, as shown by heavy lines. This plane has no dihedral. Twin tails are canted (tilted), as shown.

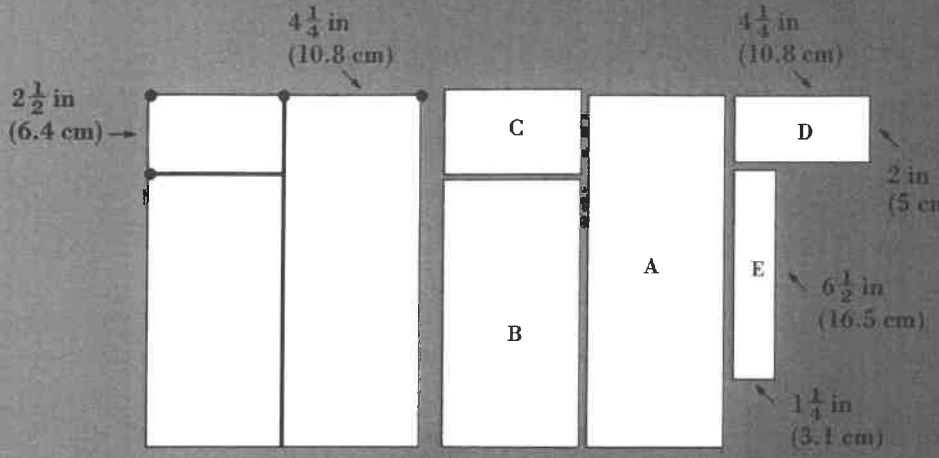


The type of airplane being planned is probably small, carrying no more than ten passengers. This small size would be one way of making the boom produced in supersonic flight less damaging. The goal is to make the plane capable of traveling nearly twice the speed of sound. It will probably be built of lightweight composite materials and use computers for flight control. The plane's main wings will be delta wings with winglets at the tips. Winglets help direct the airflow over the wings. Canard wings for added control will also be used. This plane might be the business jet of the future.

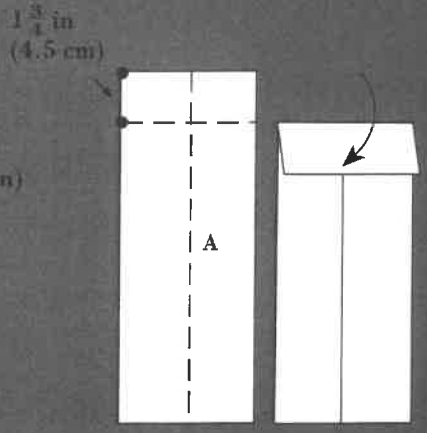
HISTORICAL INFORMATION

Flying faster than the speed of sound can only be done in areas of the world where no people live, because the loud sonic boom would break the windows in people's houses. Therefore, supersonic flights are undertaken only between cities across the world's oceans. However, the Sukoi and Gulfstream airplane companies are experimenting with planes of different shapes and sizes to see if they can reduce the intensity of the sonic boom. If the boom can be made quieter, supersonic air service between cities on the same continent or even in the same country would be possible. This paper airplane is modeled on a plane that has not yet been built. It is a concept of a future supersonic transport plane (SST).

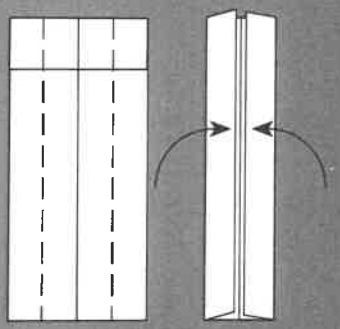
Making the SST



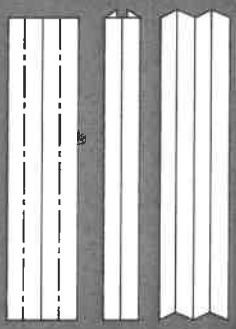
STEP 1 Measure and cut the various pieces from a sheet of bond paper. Two additional pieces, D and E, are needed, as shown.



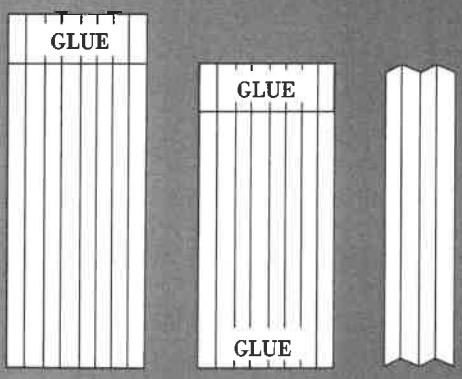
STEP 2 To make the fuselage, fold piece A in half vertically using a valley fold. Unfold. Measure from top and valley fold, as shown.



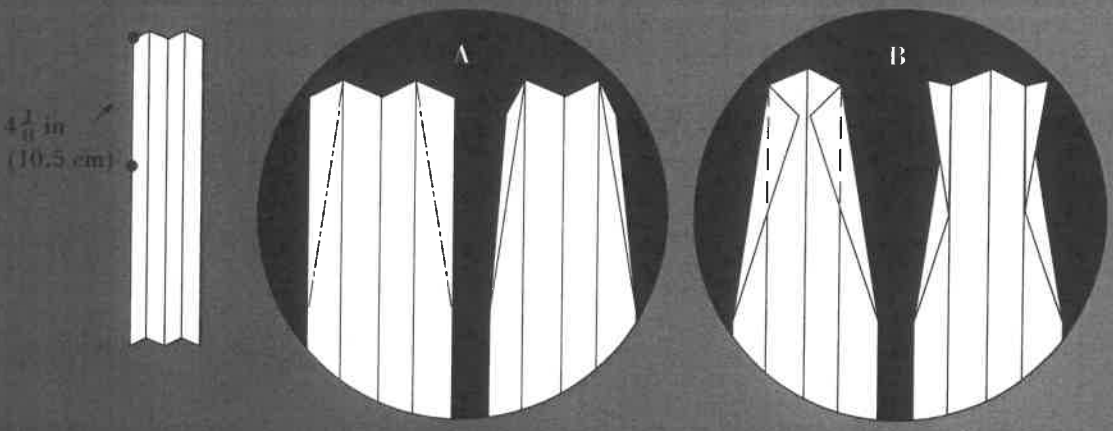
STEP 3 Valley fold each side so that outer edges meet center crease, as shown.



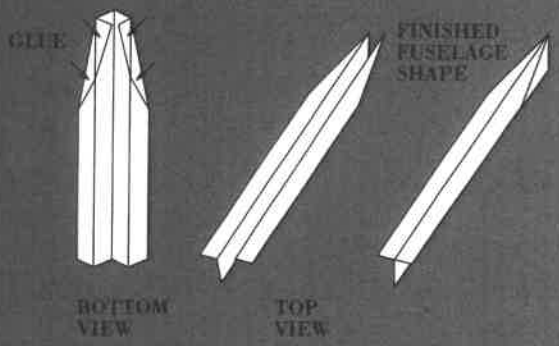
STEP 4 Fold each side again using a mountain fold, so that outer edges meet center crease at back. Then adjust folds so that paper looks like an upside-down W, as shown.



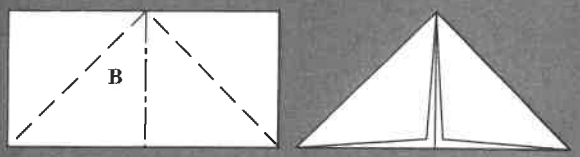
STEP 5 Unfold fuselage completely. Refold applying glue to contacting surfaces, as shown. Make sure fuselage is straight.



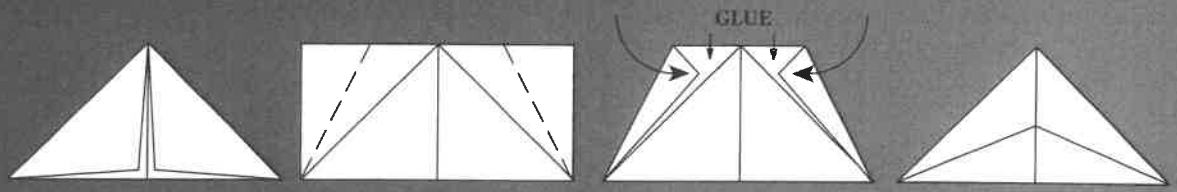
STEP 6 On each side, measure from top (front of fuselage), mark, and mountain fold along broken lines, as shown in enlarged view A. Then flip over fuselage. On each side, valley fold triangle along broken lines, matching fold line to existing crease, as shown in enlarged view B.



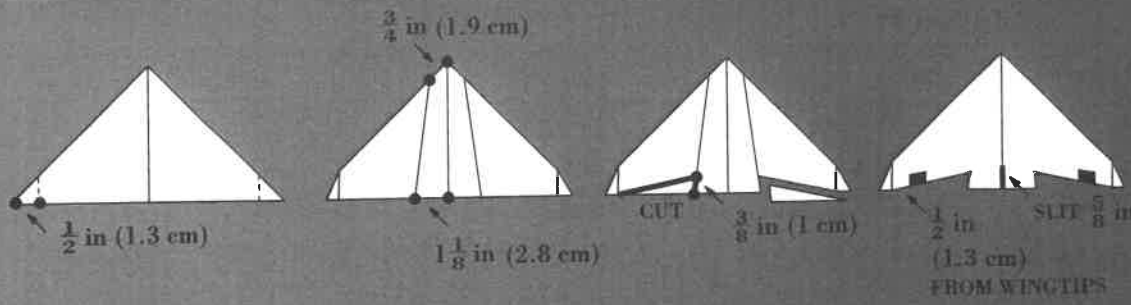
STEP 7 Glue triangles. Hold in place until glue sets. It is important that the fuselage stays straight. Do not glue nose yet.



STEP 8 Lay piece B flat in a horizontal direction to make the wings. Fold in half vertically, using a mountain fold. Unfold. On each side, valley fold diagonally so that top edge meets center crease, as shown.



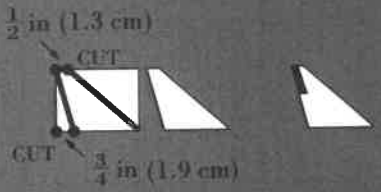
STEP 9 Unfold diagonal folds. On each side, valley fold diagonally so that outer edges meet diagonal crease, as shown. Apply glue to small upper triangles only and refold original diagonal creases.



AILERONS
$\frac{1}{2}$ in x $\frac{1}{4}$ in
(1.3 cm x .6 cm)

STEP 10 Flip wings over. To make winglets, measure at each wingtip and valley fold, as shown. Then on each side, measure and draw lines, as shown. At the trailing edge, measure and cut, as shown by heavy lines. Make ailerons in locations shown. Measure and cut a slit in location shown.

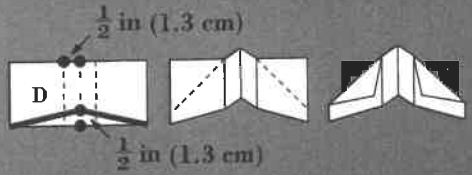
STEP 11 Lay piece C in a vertical direction. Mountain fold in half horizontally to make the vertical tail. Glue halves together.



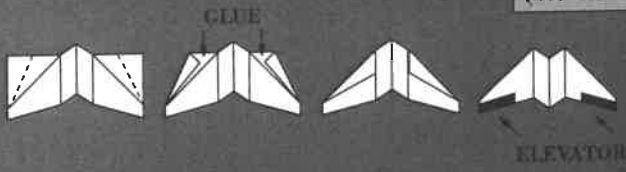
RUDDER
1 in x $\frac{1}{4}$ in
(2.5 cm x .6 cm)

STEP 12 Measure and draw lines, as shown. Cut diagonally, as shown by heavy lines. Make the rudder, as shown.

ELEVATORS
$1\frac{1}{8}$ in x $\frac{1}{4}$ in
(2.8 cm x .6 cm)



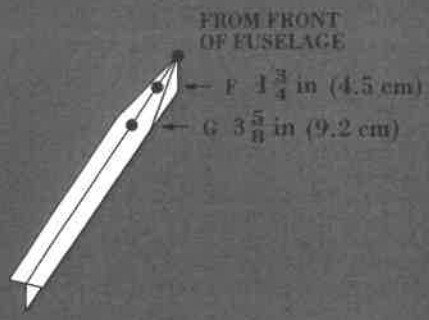
STEP 13 Lay piece D in a horizontal direction to make canard wings. Mountain fold in half vertically. Unfold. Measure from bottom along center crease and cut, as shown by heavy lines. On each side, measure and valley fold. Then on each side, fold diagonally so that top edge meets vertical crease.



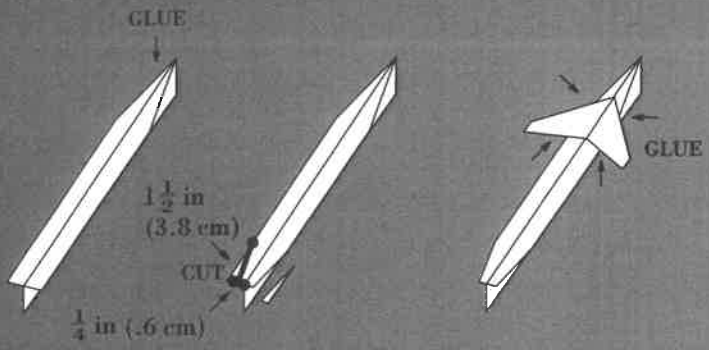
STEP 14 Unfold diagonal folds. On each side, valley fold diagonally so that outer edges meet diagonal creases, as shown. Apply glue to small upper triangles only and refold original diagonal creases. Flip wings over and make elevators in locations shown.

CANOPY (type 1)
$1\frac{1}{4}$ in x $6\frac{1}{2}$ in (3.1 cm x 16.5 cm)
Top point $1\frac{3}{4}$ in (4.5 cm)
Back $\frac{3}{8}$ in (1 cm)

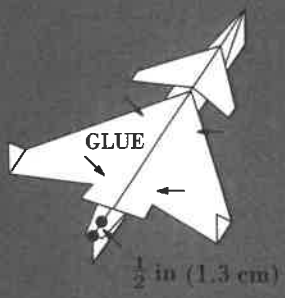
STEP 15 Use piece E to make a type 1 canopy (see p 28).



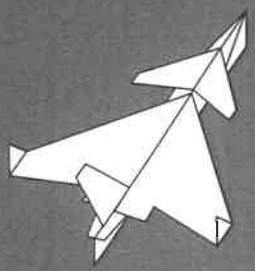
STEP 16 Measure from front of fuselage and make marks for positioning the leading edges of canard wings and canopy at F and main wings at G, as shown.



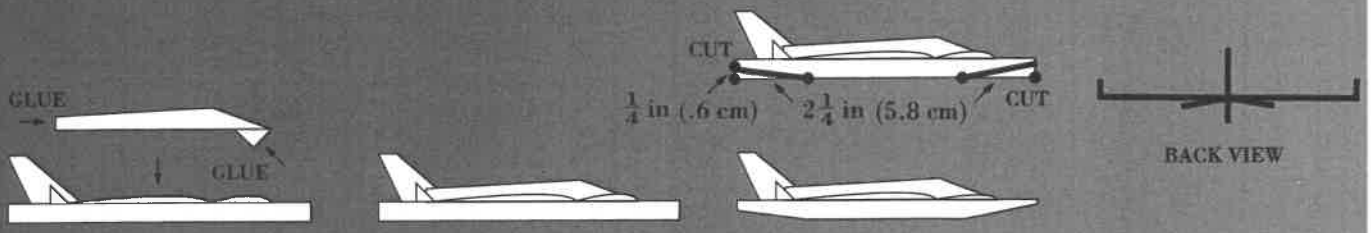
STEP 17 Apply glue to inside of nose, no more than 1 in (2.5 cm) from tip. Hold until glue sets. Then measure and cut back of fuselage, as shown. Glue canard wings in place. (Do not glue the inside center of the canard wings.)



STEP 18 Glue main wings in place, making sure they are centered and at right angles to the fuselage. Then measure from back of fuselage and mark.

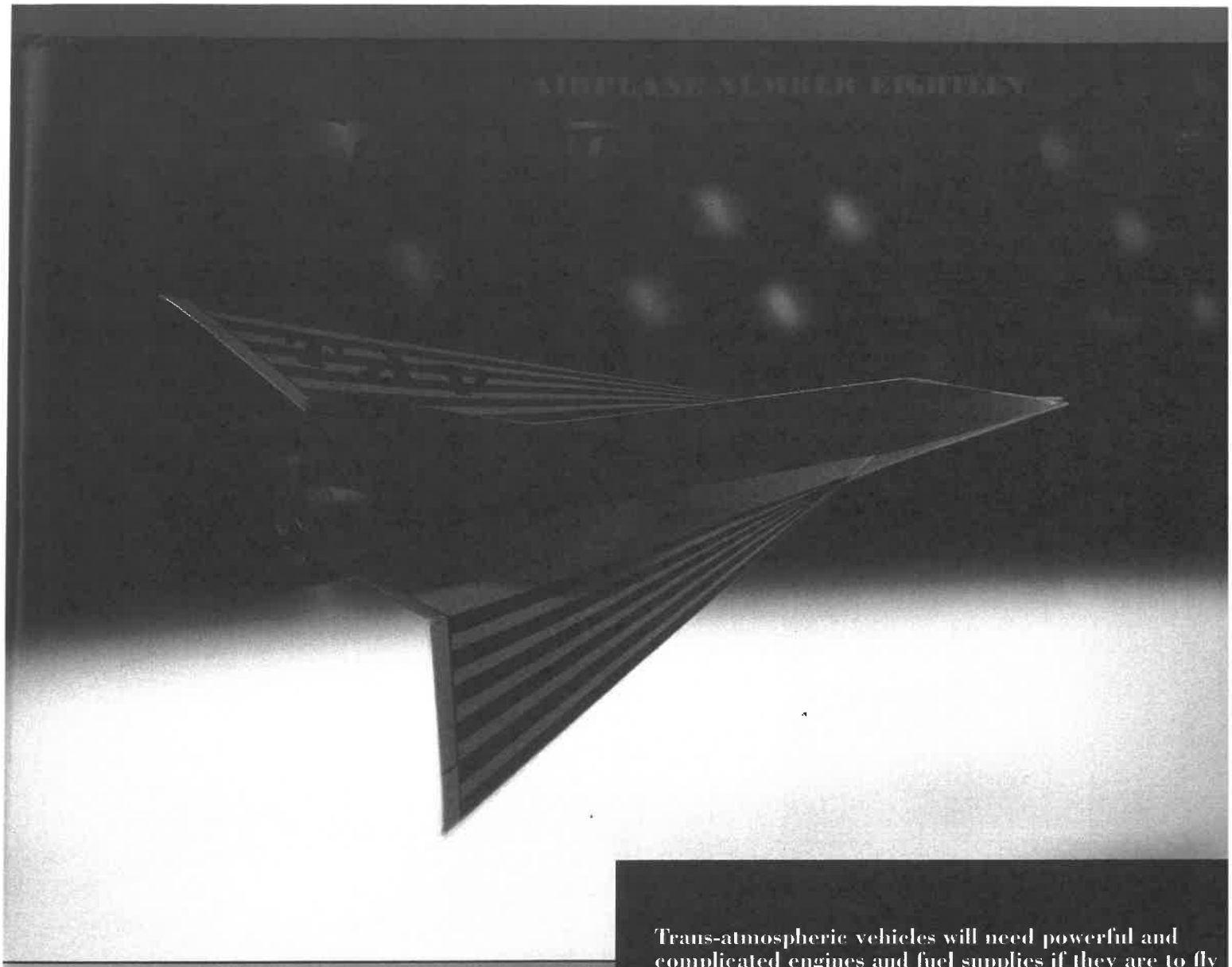


STEP 19 Apply glue and slide vertical tail into back of fuselage so that trailing edge aligns with mark.



STEP 20 Apply glue to the tabs on the bottom of canopy and the inside back of the canopy. Slide tab into center of canard wings with the slit fitting around the vertical tail. Align canopy front with front of canard wings.

STEP 21 Measure and cut nose and tail, as shown by heavy lines. The wings of this airplane have no dihedral. Adjust winglets to a vertical position.

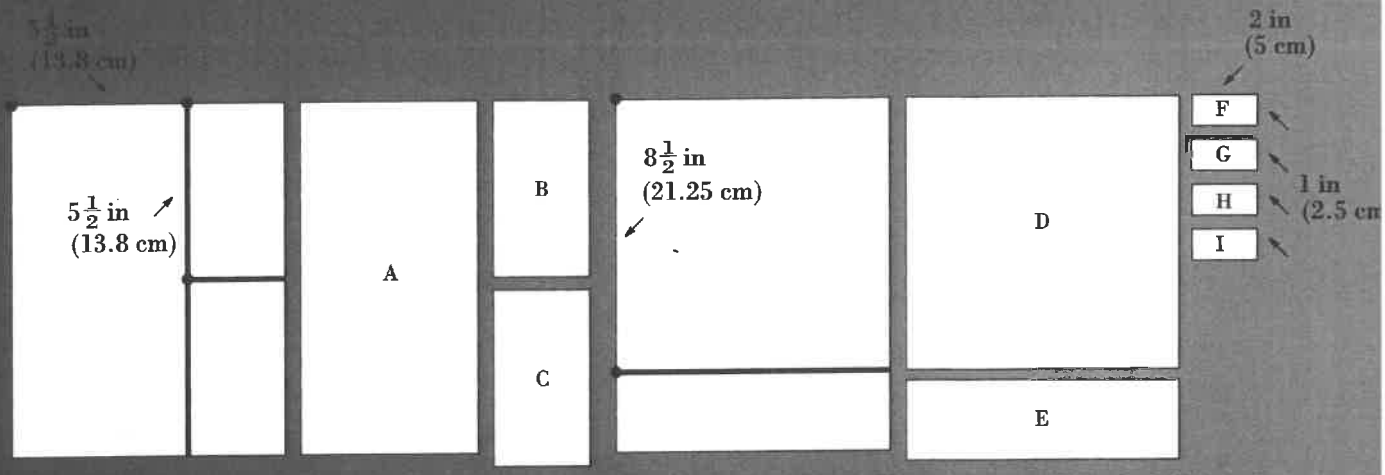


HISTORICAL INFORMATION

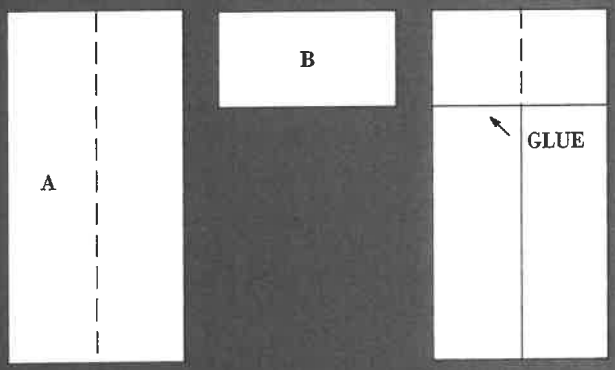
We are living on the threshold of a new era in air travel. Already the space shuttle is blasting into space attached to a rocket and returning as an airplane for another mission. The next generation of space planes will take off under their own power from ordinary airport runways, fly into space, and return back to earth. They are called trans-atmospheric vehicles (TAV). Sometimes they are called hypersonic transports (HST). They will combine jet and rocket engines for propulsion and have stable delta wings (triangle shaped) integrated into the fuselage for lift in the lower atmosphere. They will look something like the ordinary "paper plane." One example is NASAs experimental X30. This paper airplane is modeled on such future space planes.

Trans-atmospheric vehicles will need powerful and complicated engines and fuel supplies if they are to fly from the ground up into space. It takes a great deal of energy to propel an airplane beyond the limits of the earth's atmosphere and go into space orbit at 22 times the speed of sound. For example, the space shuttle we have now uses over 1,000,000 lb (600,000 kg) of liquid oxygen and 300,000 lb (120,000 kg) of liquid hydrogen, which it burns in under ten minutes of flight. The fuel is carried in large external tanks, which are thrown away during each flight. Future TAVs will carry everything on-board, like a regular airplane. In addition to engines for very high altitude, they will also have engines that can burn fuel using oxygen from the atmosphere at lower altitudes. Only at very high altitudes, where there is not enough oxygen in the air to use, will they switch to an on-board supply of oxygen. Space planes of the future will use less fuel and carry much less oxygen. Such planes will be able to fly competely around the world in just a few hours.

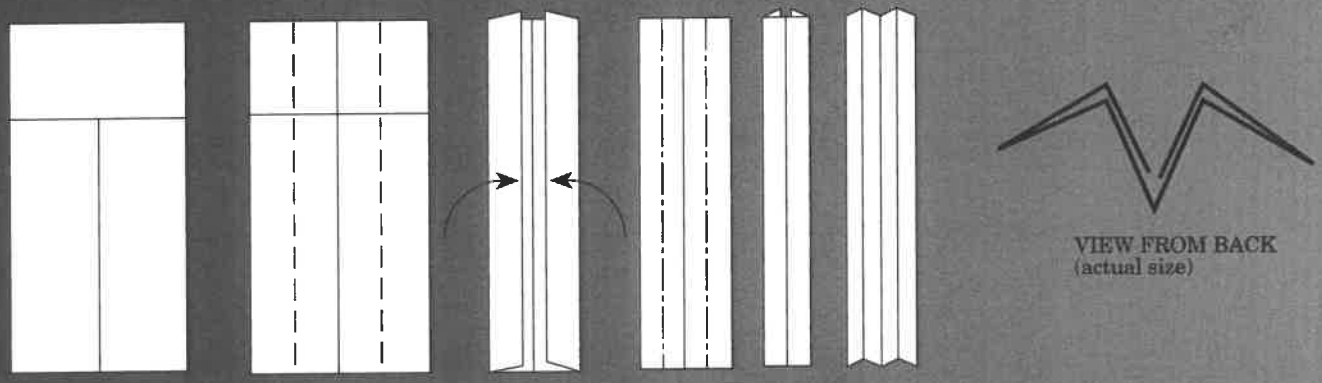
Making the TAV



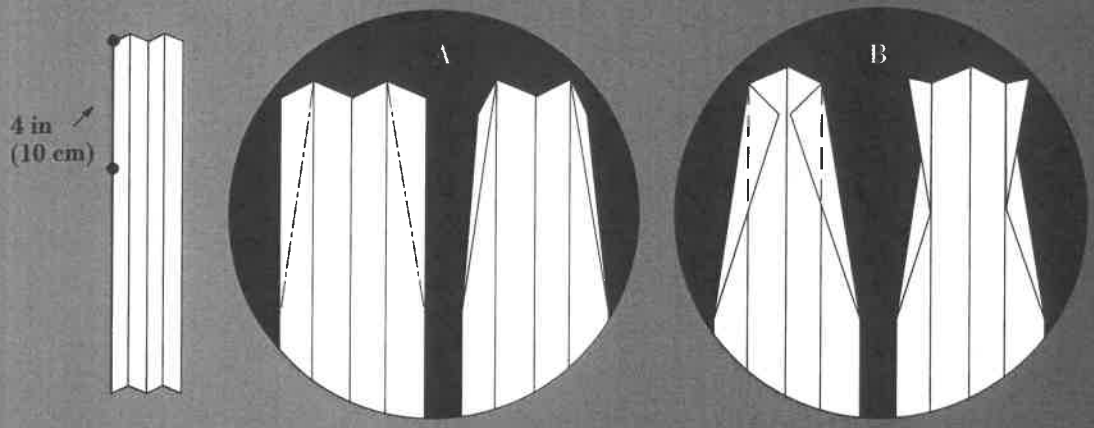
STEP 1 Measure and cut the various pieces from two sheets of bond paper. Four additional small pieces are needed, as shown.



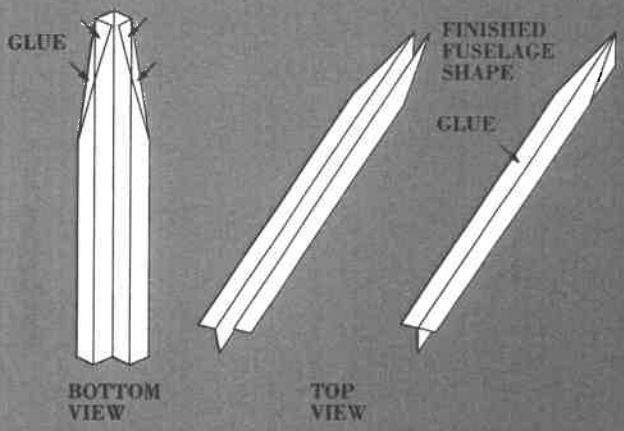
STEP 2 Lay piece A flat in a vertical direction. To make the fuselage, fold in half vertically using a valley fold. Unfold. To make nose ballast glue piece B in place, aligning the top edges, as shown. Refold center crease. Unfold again.



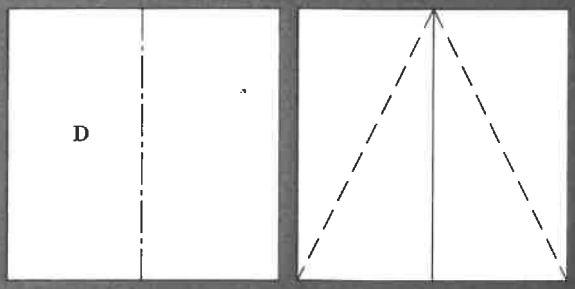
STEP 3 Refold in half vertically using a valley fold. Unfold. Valley fold each side so that outer edges meet center crease, as shown. Fold each side again using a mountain fold, so that outer edges meet center crease at back. Then adjust folds so that paper looks like an upside-down W, as shown.



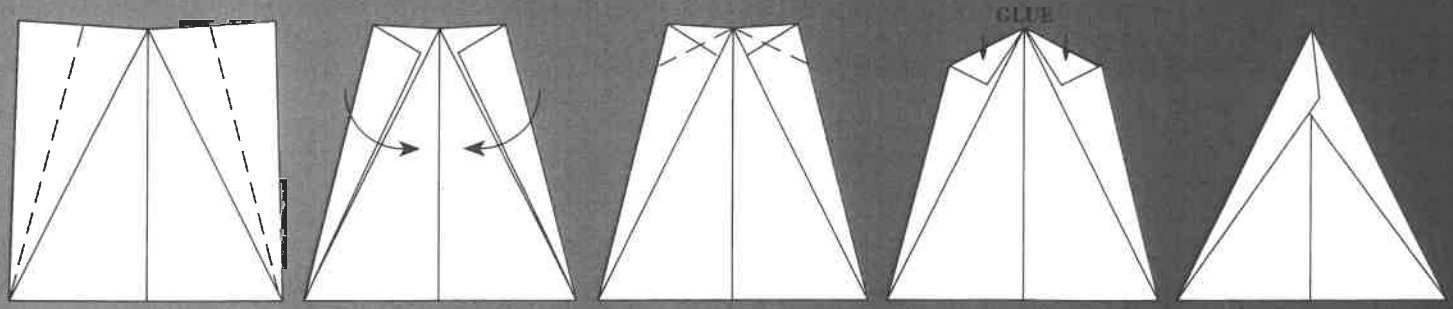
STEP 4 On each side, measure from top (front of fuselage), mark, and mountain fold along broken lines, as shown in enlarged view A. Then flip over fuselage. On each side, valley fold the triangle along the broken lines, matching fold line to existing crease, as shown in enlarged view B.



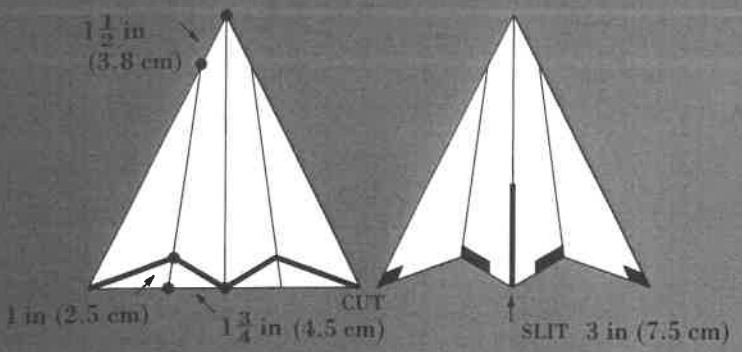
STEP 5 Glue triangles. Hold in place until glue sets. It is important that the fuselage stays straight. Glue fuselage in the middle only, leaving the nose and tail ends unglued.



STEP 6 Use piece D to make the wings. Mountain fold in half vertically. Unfold. Then on each side valley fold diagonally along a line running from the top center to the bottom corners. Unfold.

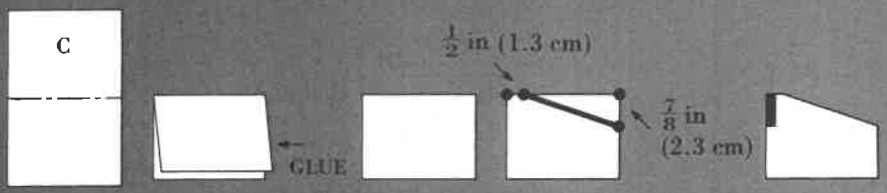


STEP 7 On each side, valley fold diagonally so that outer edges meet diagonal crease, as shown. Then fold so that upper edges meet diagonal crease, as shown. Apply glue to the small upper triangles only and refold original diagonal creases.



AILERONS	ELEVATORS
$\frac{3}{4}$ in x $\frac{1}{4}$ in (1.9 cm x .6 cm)	1 in x $\frac{1}{4}$ in (2.5 cm x .6 cm)

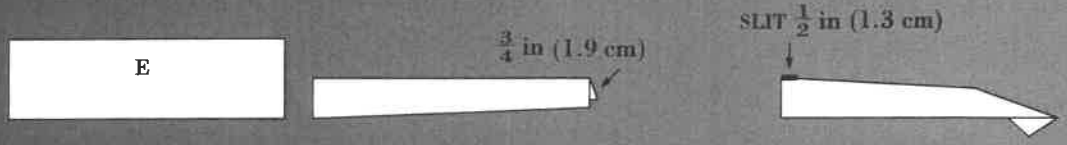
STEP 8 Lay wings flat right side up. On each side measure from front tip and back center and draw lines, as shown. Then cut wings, as shown by heavy lines. Make elevators and ailerons in locations shown. At the trailing (back) edge, cut a slit along center crease, as shown.



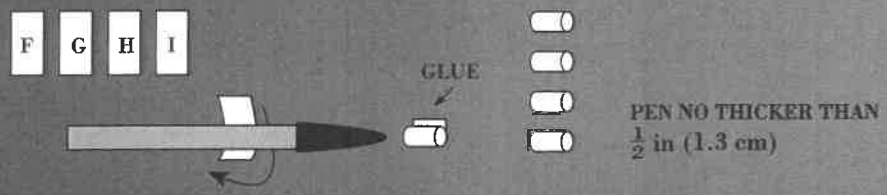
RUDDER
1 in x $\frac{1}{4}$ in (2.5 cm x .6 cm)

STEP 9 Mountain fold piece C in half horizontally to make the vertical tail. Glue halves together. Measure and cut, as shown by heavy line. Make rudder, as shown.

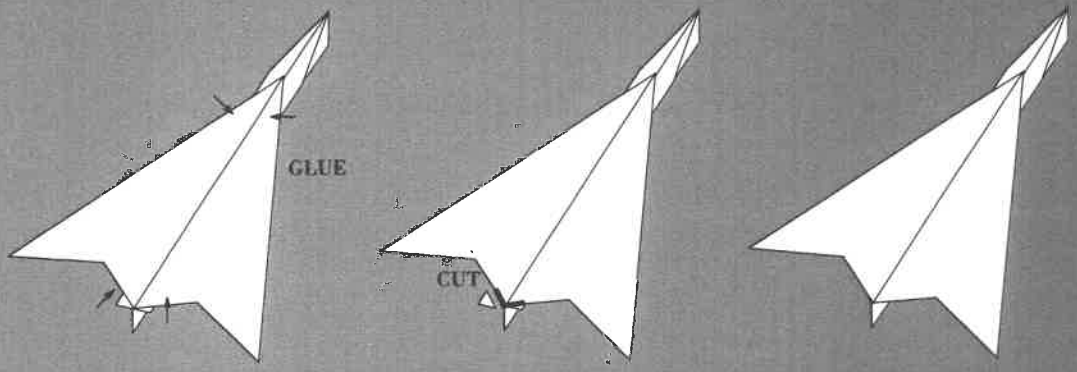
CANOPY (type 1)
3 in x 8$\frac{1}{2}$ in (7.8 cm x 21.25 cm)
Top point 3 in (7.8 cm)
Front $\frac{3}{4}$ in (1.9 cm)



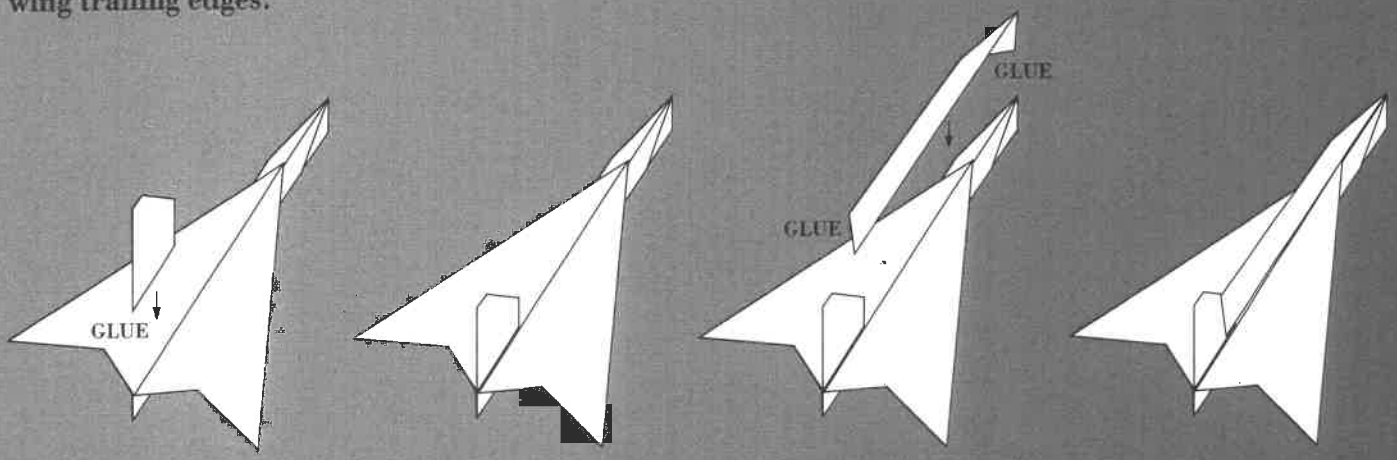
STEP 10 Use piece E to make the type 1 canopy (see p 28). Note that this canopy is lower at the front than at the back. Cut paper to size first.



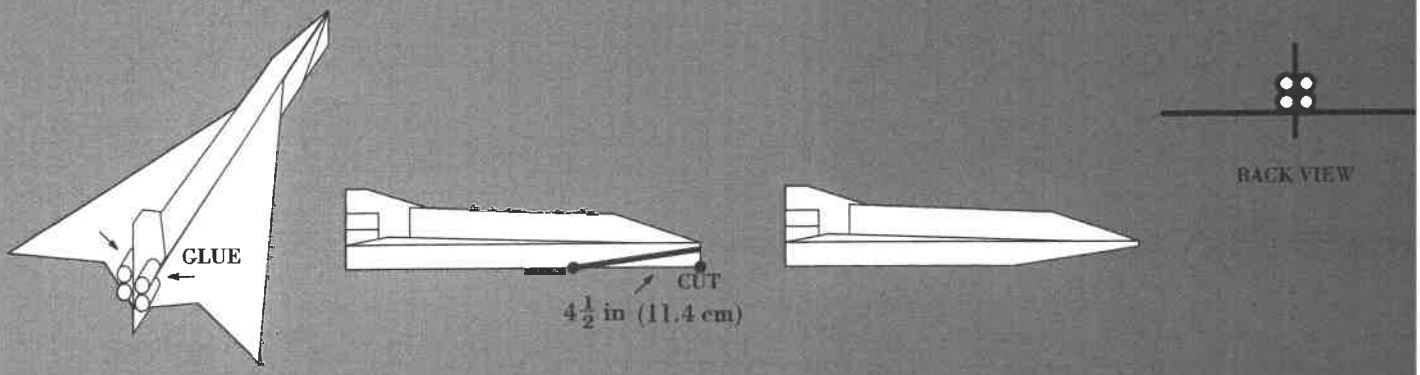
STEP 11 Use pieces F, G, H, and I to make the engines. Wrap paper around a felt pen vertically and glue.



STEP 12 Glue wings to the fuselage, aligning trailing (back) edges. Make sure wings are centered and at right angles to the fuselage. Then trim back of fuselage to match wing trailing edges.



STEP 13 Apply glue and slide vertical tail into fuselage (and the slit in the wings). Align at trailing (back) edges. Apply glue to the lower front tab of the canopy and the inside back. Position canopy by inserting tab into nose end of the fuselage and slipping the back over the vertical tail.



STEP 14 Attach the engines by gluing them to the vertical tail, two on each side, one on top the other, as shown. Align to the trailing edge of the vertical tail.

STEP 15 Measure and cut nose diagonally, as shown by heavy line. This plane has no dihedral.

Decoration

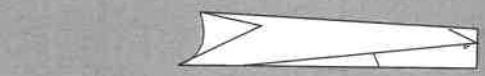
The following pages contain a plan (top) view and an elevation (side) view of each of the paper airplanes contained in this book. They have window outlines, outlines of control surfaces, and other lines that help define each plane's shape, all of which add to an airplane's realism. Decorative patterns add interest.

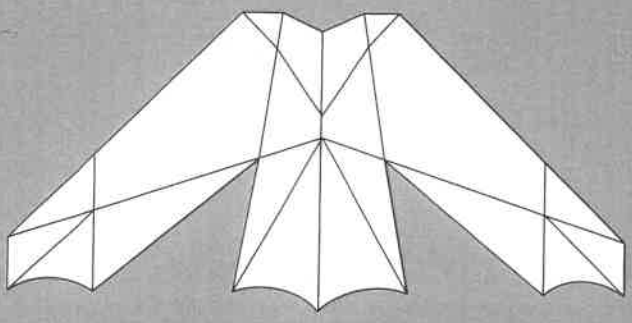
The patterns can be copied, modified, or you can invent your own. A pattern such as a checkerboard or a camouflage that is shown on one plane can easily be applied to another airplane design. Use your imagination. What you see here are suggestions. Or you can build paper airplanes and leave them undecorated. You may wish to build undecorated trial planes first so you can master their construction and flight before you spend a lot of time on decoration.

It is easier to add decoration to the airplanes before they are completely assembled. Some advanced planning is needed. Once you have decided on the pattern or design you want for the plane, decorate the pieces as you cut and fold them. Try each piece for fit and mark it carefully as you go along. Armament can be added to military planes using toothpicks. Draw the decoration lines using a very fine black felt-tipped pen. Narrow colored markers are ideal for filling in. Avoid water-based markers because they wrinkle the paper too much. Stencils can be used to add numbers and letters.

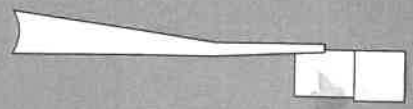
See the photographed airplanes for ideas on color schemes. Some of the patterns may be different from those shown here.

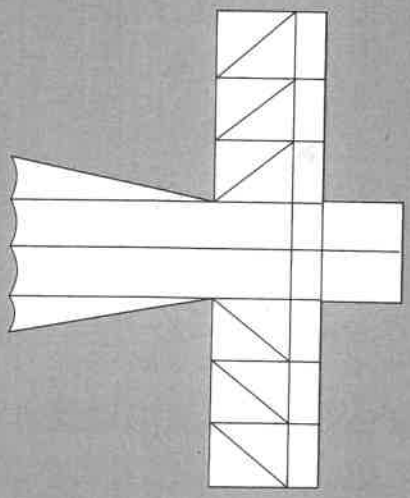
1 Aero Bat
(see p 8 for color suggestions).



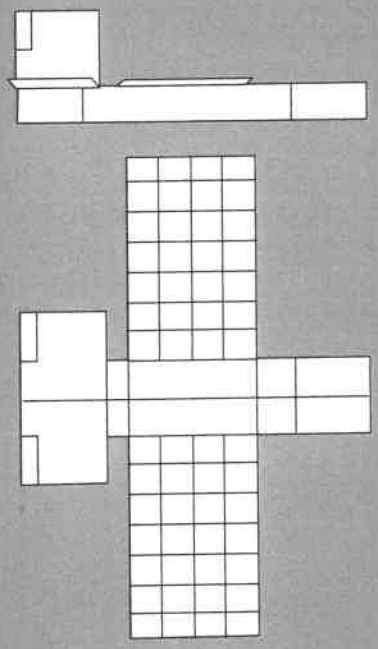


2 Sky Bird
(see p 10 for color suggestions).

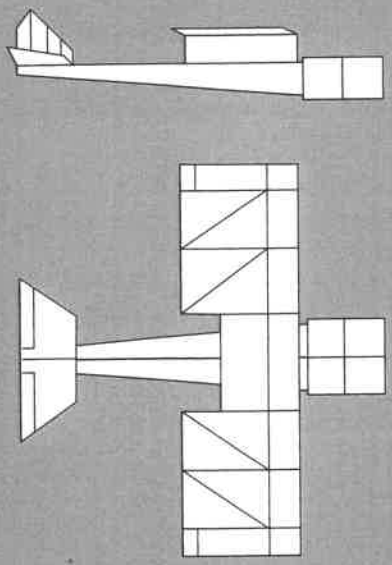




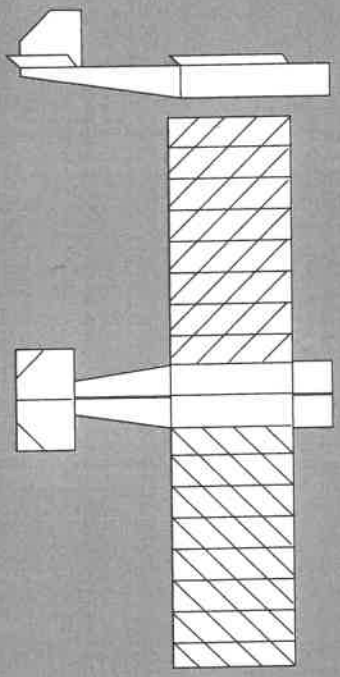
3 Plain Plane
(see p 13 for color suggestions).



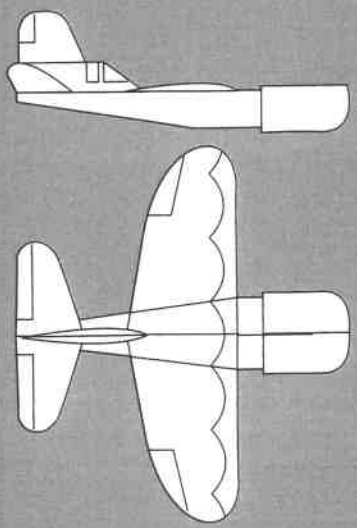
4 Biplane
(see p 16 for color suggestions).



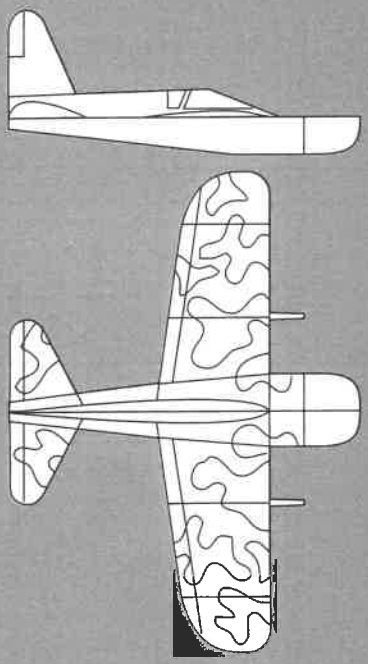
5 Aero Stunt
(see p 21 for color suggestions).



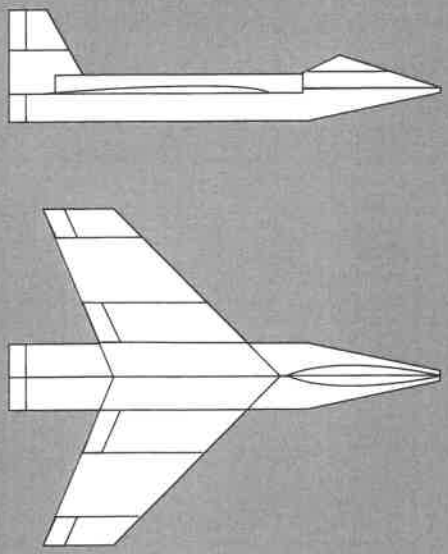
6 Gee Bee
(see p 24 for color suggestions).



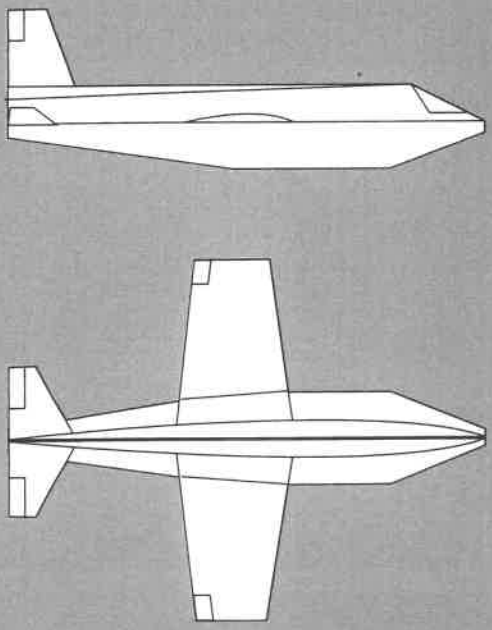
7 P47 Thunderbolt
(see p 29 for color suggestions).



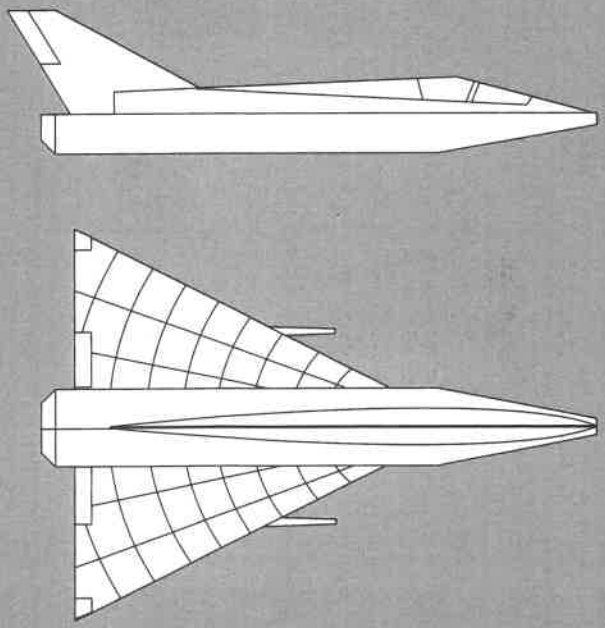
8 DH108 Swallow
(see p 33 for color suggestions).



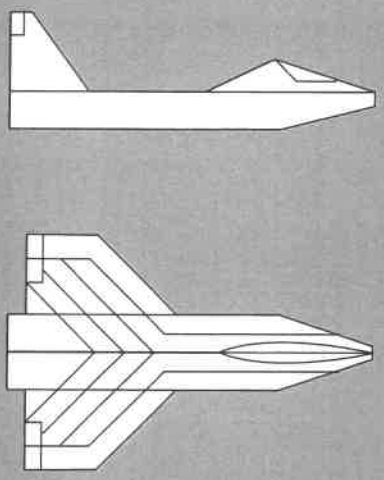
9 X1
(see p 37 for color suggestions).



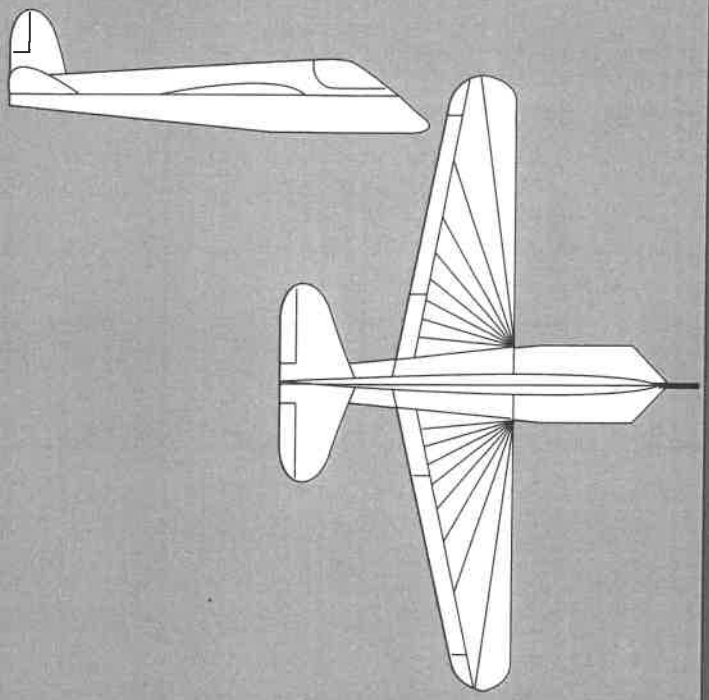
10 Mirage 2000
(see p 42 for color suggestions).



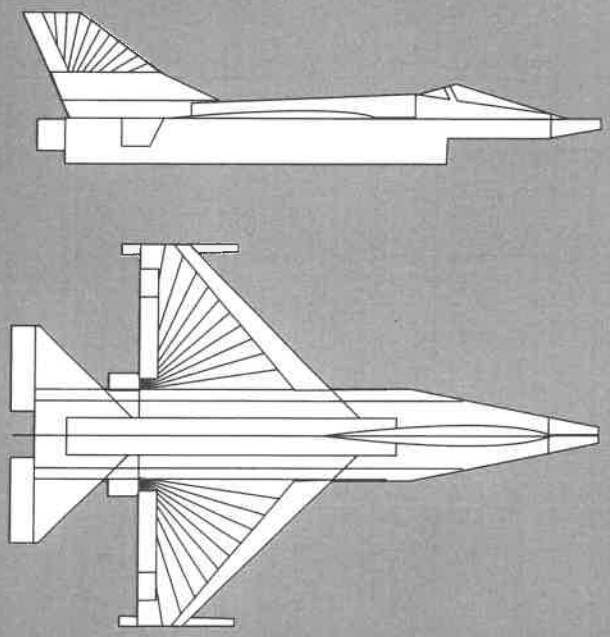
11 Lifting Body
(see p 46 for color suggestions).



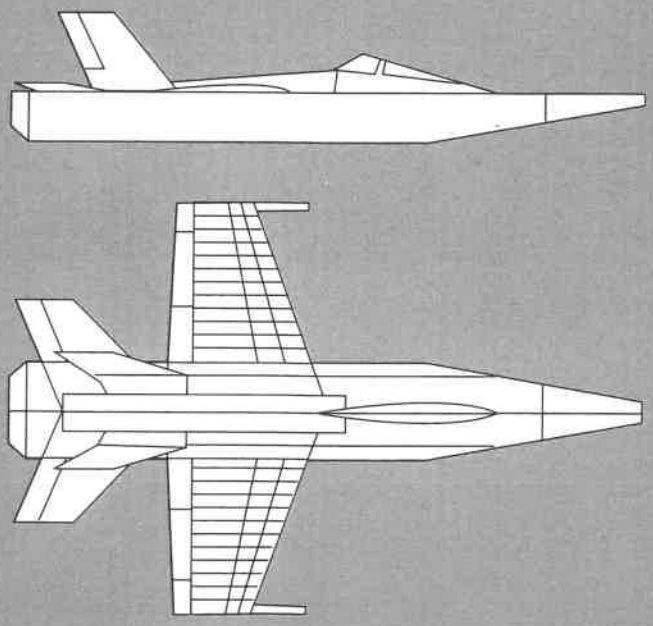
12 Glider
(see p 50 for color suggestions).



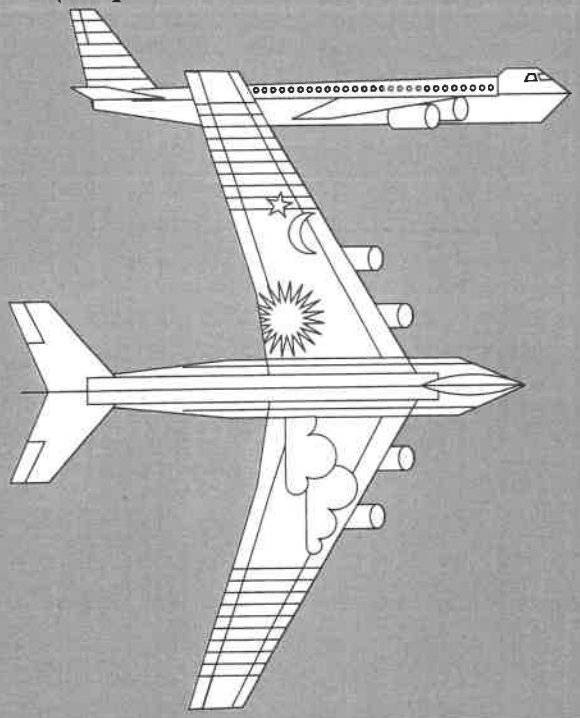
13 F16 Falcon
(see p 55 for color suggestions).



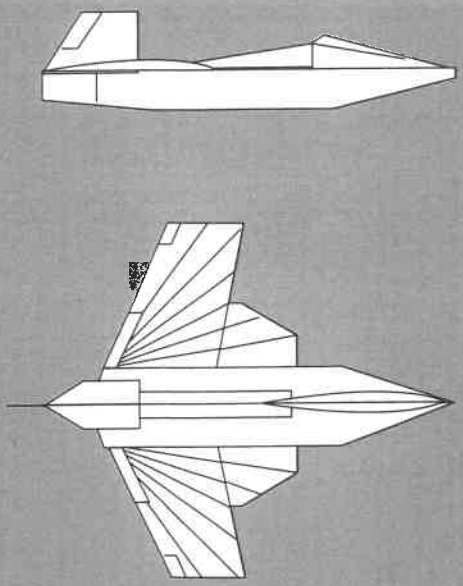
14 F18 Hornet
(see p 60 for color suggestions).



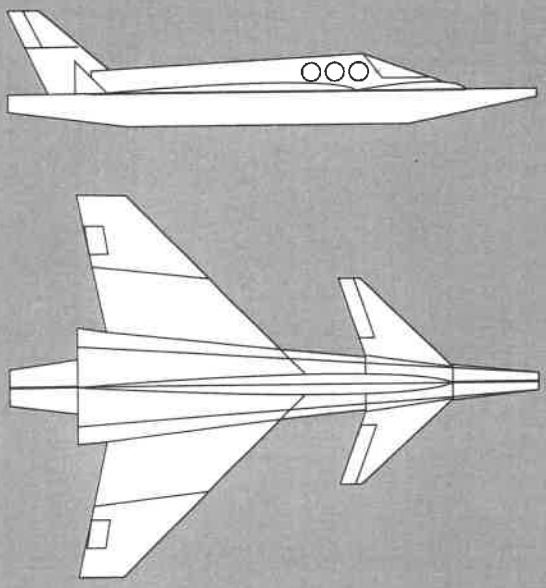
15 747 Jumbo Jet
(see p 65 for color suggestions).



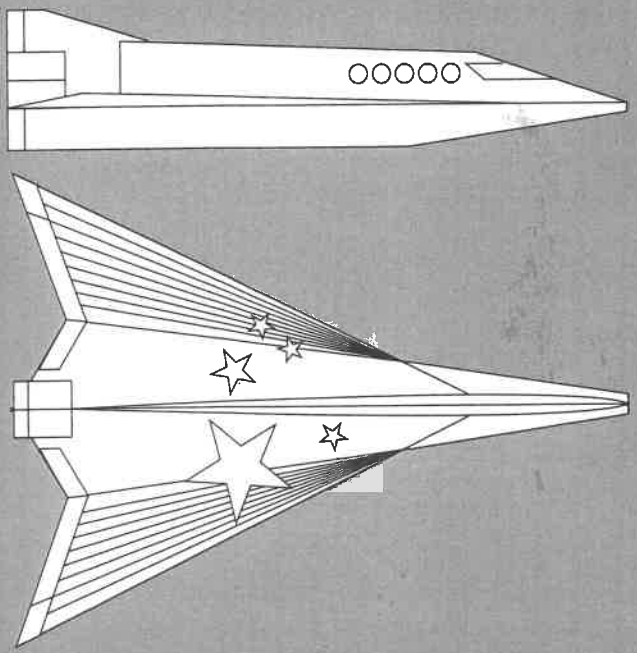
16 FSW Concept
(see p 71 for color suggestions).



17 SST Concept
(see p 76 for color suggestions).



18 TAV Concept
(see p 81 for color suggestions).



Glossary

Angle of attack The downward slant, from front to back, of a wing.

Angle of bank The raising of the outside wing and lowering of the inside wing during a turn.

Aspect ratio The length of a wing in relation to its width. The longer a wing, the higher its aspect ratio.

Attitude The direction an airplane is pointing in relation to the horizon (banking, yawing, or pitching).

Ballast Extra weight needed in the nose of an airplane to make the center of gravity coincide with the wings, which provide the lift.

Control surfaces Small surfaces that can be bent to alter the airflow and change an airplane's attitude — ailerons for bank, elevators for pitch, and rudders for yaw.

Dihedral angle Upward slanting of wings away from the fuselage. (Downward slanting is called anhedral.)

Drag The resistance of air on moving objects, slowing them down.

Fuselage The body of an airplane.

Leading edges The front edges of wings, tails, or other parts.

Lift The force of air pressure beneath the wings buoying up an airplane.

Maneuver Skilfully making an airplane fly in a desired direction — turn, climb, dive, stall, spin, or loop.

Pitch Nose up or nose down attitude.

Roll Rotation along the length of an airplane.

Spar The main internal frame that supports the wing.

Strakes Wedge-shaped extensions of the wing's leading (front) edges near the fuselage.

Trailing edges The back edges of wings, tails, or other parts.

Trim Making small adjustments to the control surfaces to affect the attitude of an airplane.

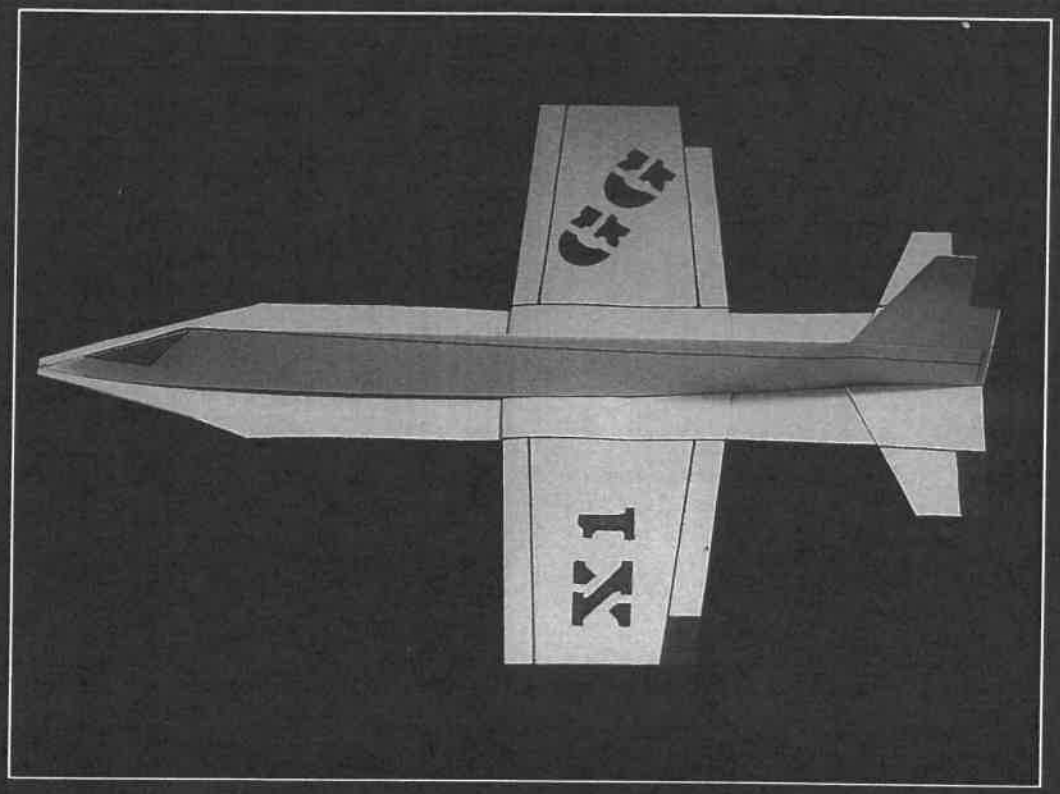
Trim drag The drag (resistance) produced from bending control surfaces into the airflow.

Ventral fin A small stabilizer on each side of the fuselage underneath the tail.

Wing loading The amount of weight a given area of wing is required to lift.

Yaw Nose left or nose right attitude.

SCIENCE/CRAFTS



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